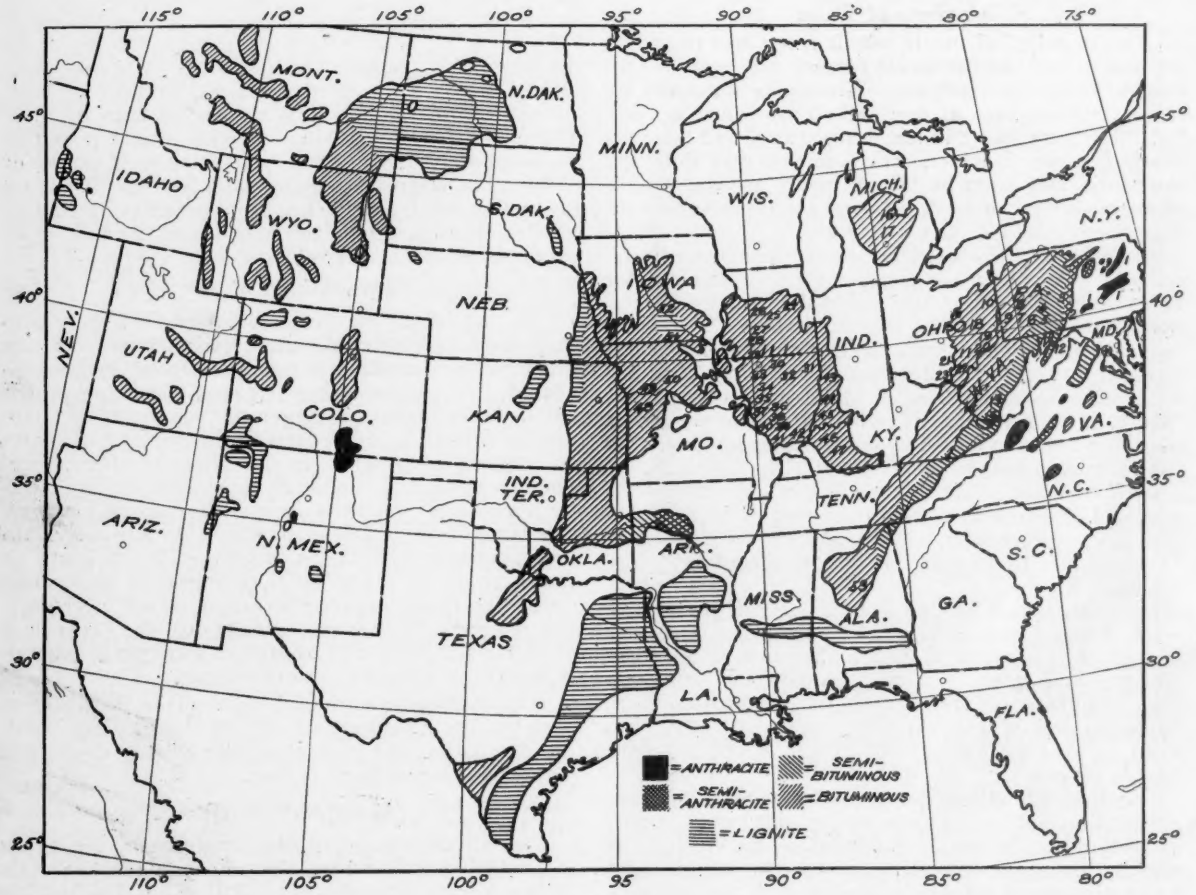
PRACTICAL ENGINEER

A monthly journal, devoted to the economical generation and utilization of power and the interests of stationary engineers

VOL. XIV. CHICAGO, JANUARY, 1910. No. 1.

COAL PRODUCING AREAS OF THE UNITED STATES



1, Anthracite; 2, Broad Top; 3, Clearfield Co.; 4, Cambria Co.; 5, Somerset Co.; 6, Connellsville; 7, Westmoreland; 8, Allegheny River; 9, Pittsburg; 10, Mahoning Valley; 11, Hocking Valley; 12, Georges Creek; 13, New River; 14, Thacker; 15, Pocahontas; 16, Carrollton; 17, Saginaw; 18, Massillon; 19, Steubenville; 20, Martins Ferry; 21, Zanesville; 22, Shawnee; 23, Coalton; 24, Coal City; 25, Streator; 26, Spring Valley; 27, Farmington; 28, Cuba; 29, Ashland; 30, Decatur; 31, Danville; 32, Shelbyville; 33, Carlinville; 34, Mt. Olive; 35, Edwards; 36, Carlyle; 37, Belleville; 38, Duquoin; 39, Carbondale; 40, Murphysboro; 41, Carterville; 42, Marion; 43, Brazil; 44, Sullivan; 45, Washington; 46, Earlington; 47, Greenville; 48, Jordon; 49, Waverly; 50, Bevier; 51, Appanoose; 52, Colfax; 53, Birmingham.

CHEMISTRY OF COMBUSTION

ELEMENTS AND THEIR RELATIVE IMPORTANCE IN FUELS

WITHOUT doubt, the most important element in steam power plant economics is the burning of the fuel. There are so many seemingly unimportant points that affect the combustion to a degree little comprehended by the man who has not made comparison of furnace efficiencies under varying conditions of draft, methods of firing, depth of fuel bed, and so forth, that a thorough study of this feature of power plant operation is time well spent by every man concerned with the generation of steam.

So far as the power plant is concerned. we may consider combustion as the chemical union of oxygen with the elements of the fuel for which it has an affinity. When this union takes place a certain definite amount of heat is generated by each pound of combustible, according to what element is united with the oxygen, or as more commonly termed, burned.

Elements of Fuels

The principal elements which enter into the combustion of fuels in the boiler furnace are oxygen, carbon, hydrogen and sulphur. There are a number of other elements such as iron and silicon found in coal, but these are usually in small quantities, and have no heating value whatever, which means that they are impurities and must be thrown away as ash, with a consequent loss of heat, as they are discharged at a higher temperature than they enter.

Fuels commonly used in power plants, such as coal, peat, wood and so forth, contain these elements in varying proportions, usually in the combined state, though in some cases the element is free.

Oxygen, which is the universal supporter of combustion, that is, the element which unites most readily with other elements, and is found most common in nature, is an invisible gas, with an atomic weight of 16. It is found in air, of which it makes up about 1/5 the volume, in the uncombined state. In the combined state it exists in water in chemical union with hydrogen, and also in coal and all other vegetable products in varying proportions with carbon and hydrogen. It varies from 1 to 25 per cent in coal according to the grade.

Carbon, which has an atomic weight of 12, is a solid, found in its pure state in diamonds, charcoal, and graphite; combined with hydrogen it is found in oils, tars and gases, in varying proportions. All vegetable products contain carbon in combination with hydrogen and oxygen. It is the principle heating element in coal and most other fuels, whether solids, liquids or gases.

Hydrogen is a light combustible gas, which always exists in a combined state in nature, and has an atomic weight of 1. It can be produced as an element by passing a current of electricity through water. Also by passing steam through white hot coal, the hydrogen and oxygen of the steam are separated, the oxygen combining with the carbon, making carbonic oxide, CO, and leaving the hydrogen in the uncombined state. This mixture of carbonic oxide and hydrogen is called water gas. All vegetable products contain hydrogen which is held in combination with carbon and oxygen, in varying proportions.

Nitrogen is an invisible gas with an atomic weight of 14, and a very slight chemical affinity for other elements. It composes about 4/5 of the volume of the air, and as it does not unite with the elements of the fuel, it is one of the chief sources of loss in the operation of boilers. As there is no simple means of separating the oxygen and nitrogen of the air, it enters with the oxygen into the furnace at atmospheric temperature, is heated to the temperature of the furnace, and discharged uncombined with the flue gases at a high temperature, thus not only having added nothing to the heat of the furnace, but in fact having subtracted all heat necessary to raise its temperature. Nitrogen appears in coal to the extent of from 0.5 of a per cent to 2 per cent by weight. When coal containing hydrogen is distilled, by the heat of the furnace, ammonia vapor, NH_3, is given off, and when the coal is burned, the nitrogen becomes oxidized forming nitric acid, HNO_3.

Sulphur, which has an atomic weight of 32, may be considered one of the impurities which appears in fuel in varying proportions from 0.5 of a per cent to 5 per cent, since it has so little heat value, and is decidedly detrimental to the metal of the boiler. It exists principally in the form of iron pyrites, sulphite of iron, though it occasionally appears as sulphate of lime. When it exists in combination with iron, 1 pound of the sulphur is equivalent in heat value to ¼ pound of carbon, but when in combination with lime, it has no heat value whatever. When sulphur melts in the furnace it mixes with the ash and is one of the chief causes of clinker.

Composition of Air

Air, while not an element, enters so largely into the combustion process, that a consideration of its properties and makeup is highly essential in this connection. Air is a mixture of gases, consisting principally of 20.91 parts of oxygen to 79.09 parts of nitrogen by volume, or 23.15 parts of oxygen to 76.85 parts of nitrogen by weight. It also contains a small percentage of carbon dioxide in some localities, and water vapor which depends upon the relative humidity and temperature. These, however, do not enter into the engineer's calculations of proportions of grate air space, or chimney area as they appear in such small quantities that their consideration is not necessary. For ordinary engineering calculations, the proportion of 21 parts of oxygen to 79 parts of nitrogen is generally used for volumetric determinations.

The combustion of coal takes place in 3 stages, namely, the absorption of heat to the kindling point, the distillation and burning of the volatile gases, and the combustion of fixed carbon.

Absorption of Heat

During this stage of the combustion, the green fuel which has just been thrown upon the live coals of the furnace, absorbs heat until it has reached the kindling temperature; also the water which is contained in the fuel is driven off in the form of steam. By the kindling temperature is meant the temperature at which the elements contained in the coal will unite with the oxygen, of the air. This temperature varies according to the constitution of the fuel, the following being given by Stromeyer, for various fuels now in common use in power plants: Lignite dust, 300 deg. F.; sulphur, 470 deg.; dried peat, 435 deg.; anthracite dust, 570 deg.; lump coal, 600 deg.; coke, 800 deg.;

anthracite lump, 750 deg.; carbon monoxide, 1211 deg.; hydrogen, 1100 deg.

Distillation of Volatile Gases

During this stage in the combustion process of coal, the hydrocarbons such as olefiant and marsh gas, tar, pitch, naphtha and the like are driven off in the form of gases. Where volatile sulphur is contained in the coal, this is also driven off in the form of sulphur dioxide. During this process also the gases are decomposed into their elements, and combined with the oxygen of the air supplied through the grate of the furnace. The products of combustion being carbon monoxide or carbon dioxide and water in the form of vapor. Where sulphur exists in the coal, the sulphur dioxide, driven off by the distillation process, combines with water to form sulphuric acid.

Combustion of Mixed Carbon

After the volatile gases have been driven out of the fuel, if sufficient air is supplied to the remaining solid portions, the fixed carbon of the fuel unites with the oxygen of the air to form carbon dioxide. If, however, the air supply is insufficient, the product of combustion will be a mixture of carbon dioxide, and carbon monoxide gases. That which remains after complete combustion of fuel has taken place, is, of course, ash.

CHEMICAL CHANGES

WHEN a single element in an uncombined state is burned in oxygen the chemical change which takes place is the simple union of the 2 elements, in proportion to their chemical affinity for each other and their atomic weights, the combustion being complete when the element has taken on all the oxygen for which it has an affinity. Thus when carbon is burned in an atmosphere of oxygen, if sufficient oxygen be supplied, the product of the combustion will be carbon dioxide, CO_2. If, however, the oxygen provided is not sufficient for complete combustion, the product will probably be carbon monoxide, CO. Again, when hydrogen is burned in air the product of combustion is water, H_2O, the hydrogen having united with the oxygen of the air in the proportion of 2 atoms of hydrogen to one of oxygen, the proportion of each element in the compound being in accordance with its atomic weight.

Chemical changes which take place in fuel upon combustion are not, however, as simple as this, since the only element which appears uncombined in coal is carbon, and this also appears in the combined state in the volatile gases; so that, in order to have complete combustion the volatile gases must be decomposed into their elements, and these elements then united with the oxygen of the air, the latter process being the only one in which heat is generated.

For example, suppose that a sample of coal contains a percentage of marsh gas, CH_4. Upon heating this gas to the kindling temperature it is broken up into its elements, carbon, C, and hydrogen, H, which in turn unite with the oxygen of the air, forming carbon dioxide and water. In a similar manner the olefiant gas C_2H_4, which exists in the fuel, is broken up and its elements united with the oxygen, forming the same products but in different proportions, when the combustion is complete.

Heat to Break up Fuel into Elements

Just as it takes considerable heat to cause the physical change of water into steam without raising its temperature, so does it take heat to break up a chemical compound into its elements. For example, if 1 lb. of hydrogen gas is burned to water, 62,032 B. t. u. are generated. One pound of carbon burned to carbon dioxide, liberates 14,647 B. t. u. Now if one pound of marsh gas, which is a compound of hydrogen and carbon, CH_4, is burned in oxygen, the product of combustion would be a mixture of carbon dioxide and water vapor and the heat given off would be 23,513 B.t.u., which is the result obtained by a calorimeter. In the case of the 1 lb. of marsh gas we have ¾ lb. of the element carbon, and ¼ lb. of hydrogen, (this proportion being calculated from the atomic weights) which if burned separately in oxygen would yield a total of 26,416 B.t.u. of heat. This difference of 2,903 heat units may be considered that which is necessary to break up the marsh gas into its elements.

An illustration of this is seen when a furnace is fired too heavily. Thus, when the carbon of the coal near the grate is burned, forming carbon dioxide, and liberating 14,600 B.t.u. per pound of carbon, this gas

TABLE I.—HEAT GIVEN BY THE COMBUSTION OF VARIOUS FUELS IN OXYGEN AS MEASURED WITH A CALORIMETER

	Heat-units. Cent.	Fahr.	Authority.
Hydrogen to liquid water	34,462	62,032	Favre and Silbermann.
	34,342	61,816	Thomsen.
Carbon (wood charcoal) to carbon dioxide, CO_2	8,080	14,544	Favre and Silbermann.
	8,137	14,647	Berthelot.
Carbon, diamond to CO_2	7,859	14,146	"
" blac- diamond to CO_2	7,861	14,150	"
" graphite to CO_2	7,901	14,222	"
Carbon to carbo- monoxide, CO	2,473	4,451	Favre and Silbermann.
CO to CO_2, per unit of CO	2,403	4,325	"
	2,385	4,293	Thomsen.
O to CO_2 per unit of C, $= 2\frac{1}{3} \times 2403$	5,607	10,093	Favre and Silbermann.
Methane (marsh-gas), CH_4 to CO_2 and H_2O	13,120	23,616	Thomsen.
	13,063	23,513	Favre and Silbermann.
Ethylene (olefiant gas), C_2H_4 to CO_2 and H_2O	11,858	21,344	"
	11,957	21,523	Thomsen.
Benzole gas, C_6H_6 to CO_2 and H_2O	10,102	18,184	"
	9,915	17,847	Favre and Silbermann.
Acetylene C_2H_2	10,109	18,196	Calculated.
Sulphur	2,250	4,050	N. W. Lord.

passing up through the bed of coal takes up carbon from the green fuel, and is transformed into carbon monoxide.

The heat generated by burning 1 lb. of carbon to carbon monoxide is 4,450 B.t.u., so that when the carbon dioxide is reduced to carbon monoxide, the amount of oxygen used is equivalent to that required to burn 2 lb. of carbon to carbon monoxide, which would generate 8,900 B.t.u., while if burned to carbon dioxide, this amount of carbon would give 29,200 B.t.u. Thus it will be seen that 20,300 B.t.u. have been rendered latent. This latent heat, however, may be rendered active by bringing the gas up to the kindling temperature and supplying it with sufficient oxygen.

Heat Given Out When Combining

The reverse takes place when 2 elements combine to form a compound, that is, the heat absorbed during decomposition is generated again when the elements combine into the same compound.

It is generally considered that in the combustion of a mixed fuel, the total heat generated is equal to the sum of that generated by each of the several elements. Thus Dulong gives the following method for calculating the amount of heat to be expected from a coal, an ultimate analysis of which has been made. The amount of heat in British thermal units from 1 lb. of coal is equal to 14,600 times the percent carbon, plus 62,000 times the difference between the per cent

of hydrogen and ⅛ the per cent oxygen, plus 4,050 times the per cent of sulphur, all divided by 100.*

This formula assumes that the fuel is completely burned, the products of combustion being carbon dioxide and water. It does not apply to a mixed gaseous fuel containing carbon monoxide, nor does it appear to hold good in the case where the natural carbon gases are contained in the fuel, but for nearly all engineering purposes, the result is within the limits of the error of chemical analysis and calorimeter determination. The heat of combustion of various substances in oxygen is given in the table.

PROPORTIONS IN COMBINATION

IN ORDER to have a thorough conception as to what takes place in the boiler furnace, one must have a clear idea of the atomic theory. Chemists and physicists have proved by experiments that all chemical elements which unite with each other do so in a definite and invariable proportion. For example if we take 2 volumes of hydrogen gas and one volume of oxygen gas, mix them thoroughly and heat them to a high degree, or pass an electric spark through the mixture, they will unite into a chemical compound, which is water with the symbol of H_2O, and after this combination has taken place, completely, there will be neither hydrogen nor oxygen left.

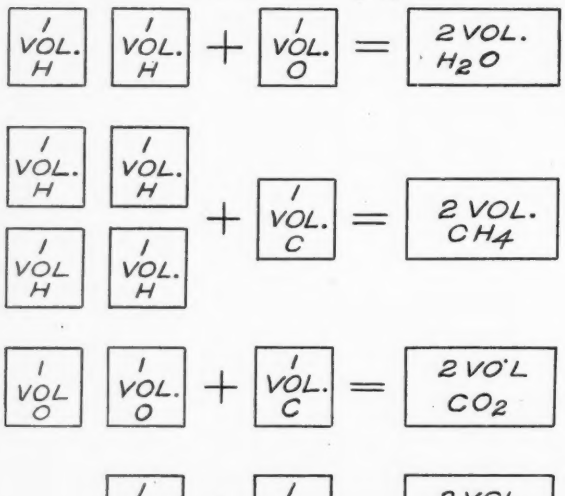


FIG. 1.—RELATIVE VOLUME OF ELEMENTS AND THEIR COMPOUNDS

Suppose that instead of the proportions taken above, we use 2 volumes of hydrogen, and 1.5 volumes of oxygen, and treat them in the same manner as before, we shall find that the hydrogen and oxygen unite in the same proportion, leaving the remainder of the oxygen uncombined. This same relationship is always maintained regardless of the quantity which may be used.

Further experiments with other elements, and compounds will prove this law to hold good in all cases. It has therefore been assumed that there is a smallest particle of matter, which may enter into combination, and that this smallest particle is of the same volume for all elements under like conditions of temperature and pressure, but that weights differ.

These smallest particles which can enter into combination are called atoms. They never exist alone, but each is held in combination with another of its own kind or with 1 or more atoms of another kind. The individual particles, resulting from the combination of these atoms, are called molecules and substances composed of molecules made up of like atoms are called elements.

The diagrams in Fig. 2 show graphically the grouping of the atoms in molecules. The first represents a molecule of marsh gas, CH_4, the next a molecule of carbon dioxide gas, CO_2; ammonia gas, NH_3, is represented as indicated. Molecules of elements are composed of 2 like atoms bound together in chemical union and take the form indicated for oxygen, O, and hydrogen, H, shown in the cut. More complex molecules are represented by combining the symbols for the elements similarly to that shown in the illustration for sulphuric acid, H_2SO_4.

Symbols

In order to simplify calculations in chemical experiments, chemists have adopted a system of symbols, by which the various elements and compounds are represented. This system consists of representing each element by the first letter of its name, or where complication exists, by the first 2 letters, or the initial letter of its Latin name. Molecules are represented by a series of letters, representing the elements which are in combination.

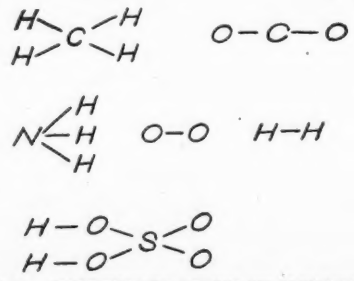


FIG. 2.—POSITION OF ATOMS IN MOLECULE

In the case of compounds where the combining elements are not in the same proportion, a small figure is placed below the center, to the right of the symbol representing the element. For example the symbol for carbon is C, that of oxygen, O. These 2 elements combined to form carbon-dioxide for which the symbol is CO_2. This means that 1 volume of carbon gas united with 2 volumes of oxygen gas are used in the compound carbonic acid gas (carbon dioxide).

Atomic Weight

As has been intimated above, all atoms are assumed to be of the same size. This assumption being true it will readily be seen that assuming 1 element as a standard, and comparing its weight with others under like circumstances, we can get a comparative weight similar to specific gravity. Hydrogen, being the lightest gas known, has been assumed as the standard, and the weight of one of its atoms is assumed as one, that is, it has an atomic weight of one. Oxygen is 16 times as heavy as hydrogen, therefore has an atomic weight of 16. Other elements are compared with hydrogen in the same manner, and their atomic or combining weights secured in this manner.

Elements entering into combination do so, in pro-

*Expressed algebraically this formula becomes,

$$\text{B. t. u.} = 14{,}600\ C + 62{,}000\left(H - \frac{O}{8}\right) + 4050\ S,$$

in which B. t. u. represents the heat derived from 1 lb. of the fuel, C, H, O and S being the percentages carbon, hydrogen, oxygen and sulphur respectively.

portion to their volume as indicated by the symbol of the resulting compound, but by weight according to their atomic weights. Thus we have 2 volumes of hydrogen uniting with 1 volume of oxygen, to form water, which is an entirely different substance with different characteristics, and specific gravity. In this case we have an equivalent of 3 volumes, taking the volume of 1 atom of hydrogen as 1, uniting together and forming 2 volumes, using the same standard when the conditions of temperature and pressure are the same.

The weight, however, of the compound thus formed, is equal to the sum of the weights of the 2 elements. That is, 2 of hydrogen plus 16 of oxygen, equals 18 of water. The water is therefore composed of 1-9 hydrogen, and 8-9 oxygen by weight but by volume of ⅔ hydrogen and ⅓ oxygen.

In like manner, where carbon, with an atomic weight of 12 unites with oxygen of atomic weight 32

TABLE II. AIR REQUIRED FOR VARIOUS COMBUSTIBLES

COMBUSTIBLE				PRODUCT OF COMBUSTION				REQUIRED PER LB. COMBUSTIBLE		
									AIR	
NAME	SYMBOL	ATOMIC OR MOLECULAR WT.	DENSITY OR WEIGHT OF ONE CU. FT. LB.	NAME	SYMBOL	ATOMIC OR MOLECULAR WT.	DENSITY OR WEIGHT OF ONE CU. FT. LB.	OXYGEN POUNDS	POUNDS	CU. FT. AT 62°
				OXYGEN	O	16	0.08928			
				NITROGEN	N	14	0.07837			
HYDROGEN	H	1	0.00559	WATER	H_2O	18	———	8.00	33.9	444
CARBON	C	12	———	CARBONIC OX.	CO	28	0.07806	1.33	5.7	75
"	C	12	———	" ACID	CO_2	44	0.12341	2.67	11.3	148
CARBONIC OX.	CO	28	0.07806	" "	CO_2	44	0.12341	0.57	2.41	32
MARSH GAS	CH_4	16	0.04464	WATER / CARBONIC ACID	H_2O / CO_2	18 / 44	——— / 0.12341	4.00	16.9	222
OLEFIANT GAS	C_2H_4	28	0.07809	WATER / CARBONIC ACID	H_2O / CO_2	18 / 44	——— / 0.12341	3.43	14.5	190
SULPHUR	S	32	———	SULPHUROUS ACID	SO_2	64	0.17860	1.00	4.25	56

to form carbon dioxide, we have a molecular weight of 12, + (2 × 16), or 44. The resultant compound is therefore composed of 12/44 carbon, and 32/44 oxygen, by weight, or 12 parts C to 32 parts O.

Valence

Experiment in combining atoms and the decomposition of compounds has proved that each kind of atom under similar circumstances has a force which is equal to or a multiple of that excited by a certain class of atoms which has the least. This quantitative value in chemical force of different atoms is called their valence.

The force exerted by the hydrogen atom is taken as the unit of valence since it has the least amount of chemical force when combining with other atoms.

Elements whose atoms have the same combining force as the hydrogen atom are called monads; those with twice the atomic combining force of hydrogen are called dyads, others triads, tetrads, pentads, sentads, according as their atoms are 3, 4, 5 or 6 times as strong as the hydrogen element.

For example, 1 atom of hydrogen will satisfy 1 atom of chlorine, and by no means known to chemical science, can these atoms be made to combine in any other proportion. In order to satisfy completely 1 atom of oxygen 2 atoms of hydrogen are required; oxygen is, therefore, a dyad. In like manner we find that one atom of carbon is completely satisfied with 2 atoms of oxygen, the valence therefore, of carbon is 2 times 2, or 4, and this element is called a tetrad.

While the valence of most elements is constant, and they unite with this same force in all compounds, there are a few, of which oxygen is the most common, which have a variable valence depending upon the temperature and pressure under which the combination is formed.

Theoretical Air Required

It will be understood from what has already been said, that knowing the atomic weight of the elements, and the compound which they form, one may readily calculate the amount of any element which is required to satisfy completely a given quantity of another element with which it is to unite to form a compound. For example, where pure carbon is to unite with oxygen of the air, to form carbon dioxide, each pound of carbon represents 12/44 of the weight of the carbon dioxide which is formed, and the oxygen present in each pound of carbon dioxide is 32/44 lb.; 32/12 times 1 equals 2⅔ pounds of oxygen required for each pound of carbon. In order to furnish 1 lb. of oxygen we must supply 4.32 lb. of air since the air contains oxygen and nitrogen in the proportion of 1 to 3.32. Therefore, to burn the 1 lb. of carbon we will require 2⅔ times 4.32 or 11.52 lb. of air, which is 11.52 × 13.141 = 151.5 cu. ft. at 62 deg. F., since the volume of 1 lb. of air is 13.141 cu. ft.

Application of this calculation to furnace practice may be illustrated by taking an example where the

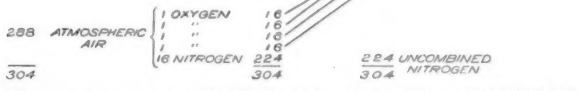


FIG. 3.—GRAPHIC ILLUSTRATION SHOWING COMBUSTION OF CARBURETTED HYDROGEN

ultimate analysis of the coal is given, and working out the amount of oxygen required for each element contained in the coal. Suppose that we have coal which contains 77 per cent carbon, 5 per cent hydrogen, 2 per cent nitrogen, 1 per cent sulphur and 9 per cent oxygen with 6 per cent of ash. We further assume that the carbon is completely burned to carbon dioxide, the hydrogen to water, the nitrogen remains uncombined, sulphur passes off as sulphur dioxide, the oxygen present in the coal unites with the other elements to form carbon dioxide and water, and the ash remains uncombined.

The oxygen required to satisfy 0.77 lb. of carbon is 32 ÷ 12 × 0.77 = 2.06 lb. of oxygen. Again to supply the necessary amount of oxygen to unite with all the hydrogen, we will need 0.05 times 8 or 0.4 lb. of oxygen. The sulphur having an atomic weight of 32 unites with 2 atoms of oxygen (2 × 16 = 32) forming a compound which is half oxygen and half sulphur by weight, and the oxygen required in this case is then 0.01 times 1 or 0.01 lb. of oxygen.

The total amount of oxygen required is 2.06 + 0.4 + 0.01 = 2.47 lb. The amount of oxygen furnished by the fuel itself is 0.09 which subtracted from 2.47 leaves 2.38 lb. of oxygen to be supplied by the air. The amount of air, therefore, required to completely burn 1 lb. of coal with the above analysis is 2.38 × 4.32 = 10.28 lb. or 10.28 × 13.141 = 135 cu. ft.

Practical Supply of Air

In the above calculations, theoretical conditions have been assumed. In practice we are unable to provide perfect conditions as assumed above, with a consequence that a share of the carbon and hydrogen are only partially combined with the oxygen, and pass off in the gaseous state uncombined. This condition may be the result of imperfect mixture of the air with the

gases, insufficient time allowed after the gases have reached the incandescent state before they are brought into contact with the cold boiler flues, the cooling down of the furnace gases by the introduction of too much cold air or too heavy firing.

In order therefore to supply the required amount of oxygen in the air to complete the combustion with natural draft it is customary to supply about 24 lb. of air per pound of coal. With forced or induced draft, however, where the supply of air is under perfect control, good practical combustion may be secured by supplying even as low as 18 lb. of air per pound of coal.

Loss Due to Excess Air

For each pound of carbon burned to carbon dioxide in a furnace there must be supplied 11.5 lb. of air, and assuming that the air enters the furnace at 50 deg. F. and the temperature of the flue gas is 400 deg. F. there will be a loss of heat equal to $12.5 \times (400 - 50) \times 0.24 = 1050$ B. t. u. going to waste up the chimney, the specific heat of the gas being 0.24.

It is impossible to avoid this loss and in fact best practice requires that the amount of air supplied be from 50 to 100 per cent more than the theoretical requirements. It will therefore be seen that with the temperatures as assumed above, each pound of air supplied the furnace above what is necessary to insure complete combustion means a total loss of $(400 - 50) \times 0.24 = 84$ B. t. u. which should be eliminated as far as possible.

TESTING CORRECTNESS OF COMBUSTION

THEORETICAL REQUIREMENTS AND PRACTICAL RESULTS

IN MODERN power plant practice 3 methods are employed by the fireman or engineer in charge of the boiler room, for determining the condition of combustion in his furnace. The first, and most common, is that of observing the color of the gases from the fuel bed to the uptake.

For this purpose boiler settings are usually provided with a sight hole into the combustion chamber. Perfect combustion is indicated when the temperature of the gas reaches such a point that a bright red or white red transparent condition is maintained. After green fuel has been thrown upon the fuel bed, the gases rising from it are streaked with opaque gas, indicating that all of the combustible material has not been ignited. This gas upon entering the combustion chamber should become transparent as indicated above.

It is, of course, impossible for the operator to observe these color changes with the naked eye, and for this reason a violet blue glass is used. When this glass is used, imperfect combustion is indicated by streams of dark through which the opposite side of the furnace cannot be seen, perfect combustion being indicated by a clear lavender gray color.

Red and yellow flames are cut out by this glass and the rays from the gas passing between cold tubes of a water tube boiler will quickly show them to possess little radiant light capable of passing through blue glass. It is quite evident that smokeless combustion takes place at a temperature producing light rays which penetrate blue glass, thus indicating a high actinic power and intense chemical action. The dun colored gas, rising from the coal, upon passing to the zone of perfect combustion, disappears leaving the lavender gray appearance as mentioned above. As showing the color conditions compared at different stages of combustion and temperature, the accompanying diagram presented by Houldsworth to the British Association is well worth considering. In this experiment 300 lb. of coal was thrown upon the grates at a single charge, the temperature rising rapidly in a few minutes as indicated on the chart, with color changes as noted. During the test it was noted that the temperature was dropping rapidly until when it reached 1,040 deg. the fuel was leveled which evened up the air spaces which had been formed, with the result that the temperature increased almost immediately showing the value of

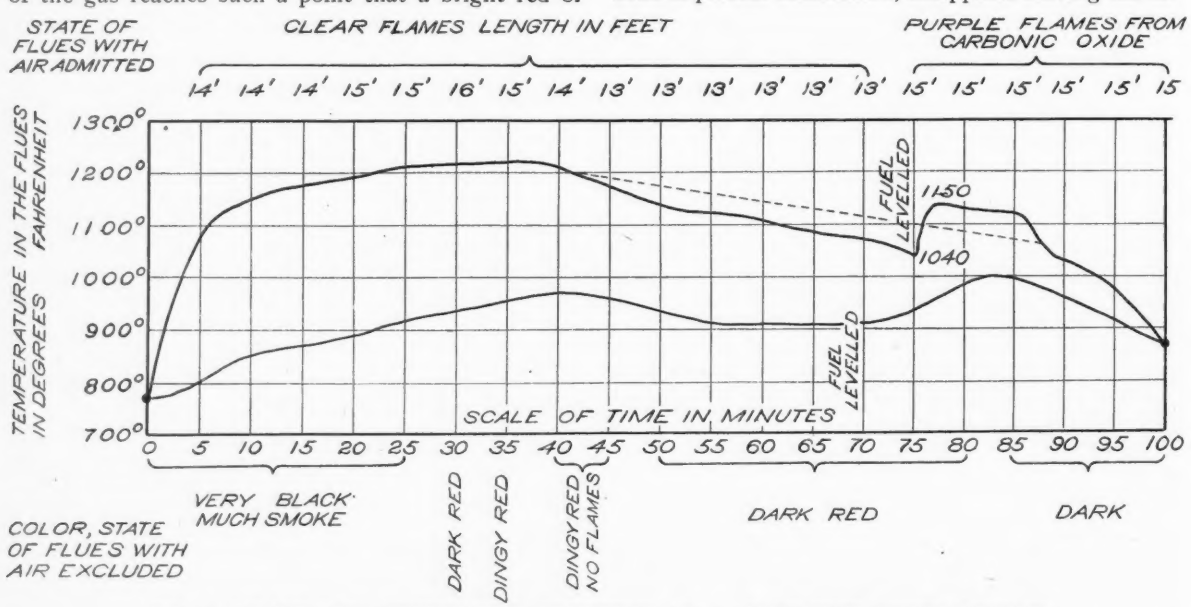

STATE OF FLUES WITH AIR ADMITTED
CLEAR FLAMES LENGTH IN FEET
PURPLE FLAMES FROM CARBONIC OXIDE
14' 14' 14' 15' 15' 16' 15' 14' 13' 13' 13' 13' 13' 13' 15' 15' 15' 15' 15' 15
TEMPERATURE IN THE FLUES IN DEGREES FAHRENHEIT
1300° 1200° 1100° 1000° 900° 800° 700°
FUEL LEVELLED
1150
1040
FUEL LEVELLED
SCALE OF TIME IN MINUTES
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
VERY BLACK MUCH SMOKE
DARK RED
DINGY RED
DINGY RED NO FLAMES
DARK RED
DARK
COLOR, STATE OF FLUES WITH AIR EXCLUDED

FIG. I.—FLAME AND TEMPERATURE CONDITIONS IN A HAND-FIRED BOILER FURNACE

this operation in hand fired furnaces. The dotted line represents what the temperature would be if an even air supply were provided during the entire process.

The lower curve shows the results obtained when an insufficient supply of air is provided.

Gas Analysis

Another method employed for determining the correctness of combustion is by means of a chemical analysis of the flue gas. By this means it is possible to determine definitely the exact condition of the combustion in the furnace. In power plant practice the volumetric determination is the most common and simplest to perform. There are upon the market a number of instruments for analysing the flue gases which are not difficult to operate and give results sufficiently accurate for practical purposes.

In order to obtain an average sample of the gas, a sampling tube should be provided which extends well into the flue from the boiler whose gas is to be tested.

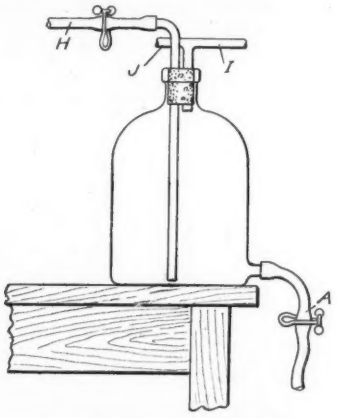


FIG. 2.—SAMPLE HOLDER

A convenient and common method is to provide an observation hole which is usually located about 24 in. on the furnace side of the damper or junction to the main flue. In this hole is inserted a wrought-iron pipe 1.75 in. in diameter, flanged at the top and set into the flue with fire clay.

When not in use this observation hole is closed by placing a 1.5 in. bolt into it.

The sampling tube may be made of Bohemian glass combustion tubing, porcelain, or water cooled metal tubes. These tubes are provided with holes all along the sides through which the gas is drawn. Care should be exercised in inserting glass or porcelain tubes as the sudden change in temperature is liable to break them.

Sample Holder

Some form of gas sample holder should be provided when it is desired to take tests of the gas at intervals. These holders should be of sufficient capacity to hold 150 to 200 cubic centimeters of gas and may be of the form shown in the illustration. The bottle is provided with a cork through which are passed 2 tubes, one of which connects through the rubber tube, H, to the water supply, and extends to the bottom of the bottle, the other extends merely through the cork and is provided with a T connection, one branch of which is connected by means of glass and rubber tubing to the sampling tube, while the other connects to the suction side of the aspirator or pump, used to draw the gas. From the bottom of the bottle is a glass tube with a rubber connection which carries the water to waste.

To operate this apparatus, the pinch cock, A, is closed and H, opened, thus allowing the water to fill the bottle completely. The pinch cock H is then closed, and J, opened, and the gas drawn through the T by the gas pump in order to remove all air which may remain in the gas connections. After this has been running for some time the pinch cock, A, is opened, thus allowing the water in the bottle to drain out and draw in the flue gas through the tube, J, when A is again closed.

In order to discharge the gas into the testing apparatus the tube I is connected to the gas instruments,

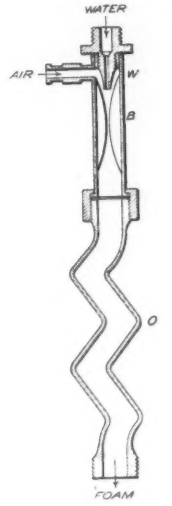


FIG. 3.—RICHARDS JET PUMP

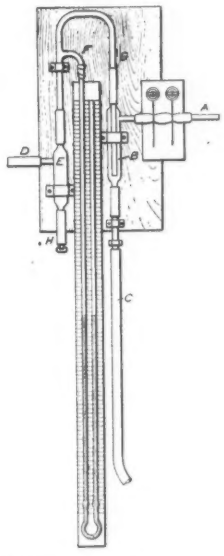


FIG. 4.—BUNSEN PUMP

the pinch cock on J closed, and by opening the pinch cock, H, water flows to the bottom of the bottle and forces the gas into the instrument.

Gas Pumps

For drawing the gas into the sampling apparatus there are 3 forms of pumps in general use. These are jet pumps, fall pumps, and steam pumps. The Richards' jet pump which is illustrated herewith consists of a water jet, resembling very much the common boiler injector with an air or gas connection and a restricted portion, B, with a zigzag tube, C, which is used for breaking up the water into foam, the principle of operation being that water entering at the top draws the air or gas through the side connection by forming successive pistons through the restricted passage.

A fall pump depends upon the weight of the water to maintain the vacum or suction. The form shown in the illustration is that devised by Bunsen, and consists of a water connection attached to an enlarged tube, B, and discharges the water through the tube, C, which, in order to maintain a perfect vacuum, should be 33 ft. in vertical height. In the enlarged tube, B, is inserted a smaller glass tube, which extends nearly to the bottom and connects at the other end through G, E and D, to the gas or air connection. The enlarged portion, E, is provided to catch any water which may be drawn back into the gas connection, and the stop cock, H, is used to drain it off. A scale and mercury U tube is provided in order to ascertain the exact vacuum maintained in the gas tubes to which it is connected through the tube F.

When it is desired to draw a sample of the gas the tube, D, is connected to a branch of the rubber tubing, I, shown on the sampling apparatus. The water connection is made through the tube, A, and by the continual falling of the water acting as a series of pistons through B and C, gas is drawn from the flue.

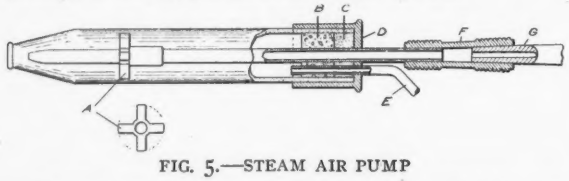


FIG. 5.—STEAM AIR PUMP

The steam air pump consists of a large tube contracted at one end into which is inserted a cork, B, and cement C fitted with a covering D, provided with a steam tube, G, and an air tube, E, the steam tube extending nearly to the contracted end of the large tubing and held in place by the washer, A. The steam connection is made through the pipe, G, and when turned on draws air or gas through the connection, E.

The Eliot Apparatus

One of the simplest and most common pieces of apparatus used for analysing flue gas is known as the Eliot, and consists of a measuirng tube, A, a treating tube, B, with a top connection, E, provided with a stop cock, F, and a 3-way cock, J. Pressure bottles, G and H, are provided with rubber connections to the tubes A and B, as indicated in the illustration.

Before using, the apparatus should be thoroughly cleaned with water which is passed through the tubes, back and forth, by means of the pressure bottles G and H. Distilled water is then put into the tubes and bottles, and the bottles placed upon the shelves provided for that purpose with the stop cocks F and J closed.

Connection is made to the gas holder through J, which is turned to open straight from the tube B. By

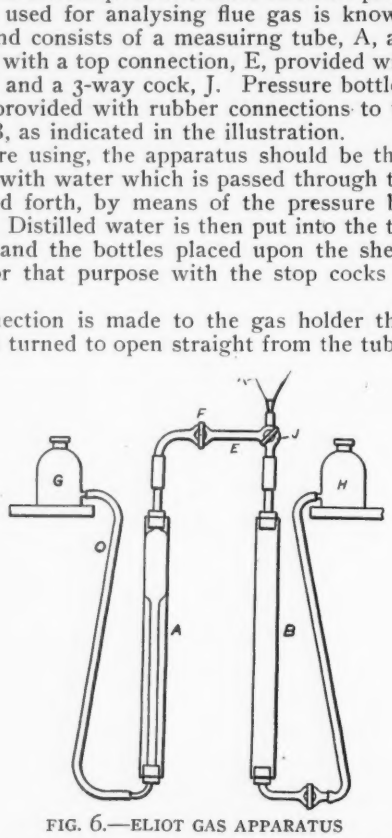


FIG. 6.—ELIOT GAS APPARATUS

lowering the bottle, H, the gas is then drawn into the treating tube when J is turned to connect B and E. By opening F, raising H, and lowering G, the gas is drawn into the measuring tube, A, the water in G being kept at the same level as in A, by raising or lowering the bottle, H. The tube, A, is graduated so that the amount of gas it contains can readily be determined from the scale, and this amount for convenience is usually 100 cubic centimeters. The stop cock, F, is then closed and with J opened, the bottle, H, is raised until all gas is expelled from the tube, B.

By turning J, E is connected to B, F is then opened and the gas passed into B for treatment.

A 5 per cent solution of caustic potash is then poured into the funnel, K, and allowed to drip along the sides of the treating tube until no further absorption takes place. The gas is then passed into A and measured, its loss in volume, which was carbon dioxide, being noted. Treatment for oxygen is then proceeded with, using, instead of the caustic potash, a solution of 5 grams of pyrogallic acid in 15 cubic centimeters of distilled water, added to 120 grams of caustic potash in 80 cubic centimeters of water, which is dropped from funnel into B, measuring the gas and noting the loss of volume due to absorbing the oxygen.

Carbon monoxide is then absorbed by a solution made from 10.3 grams of copper oxide in 100 cubic

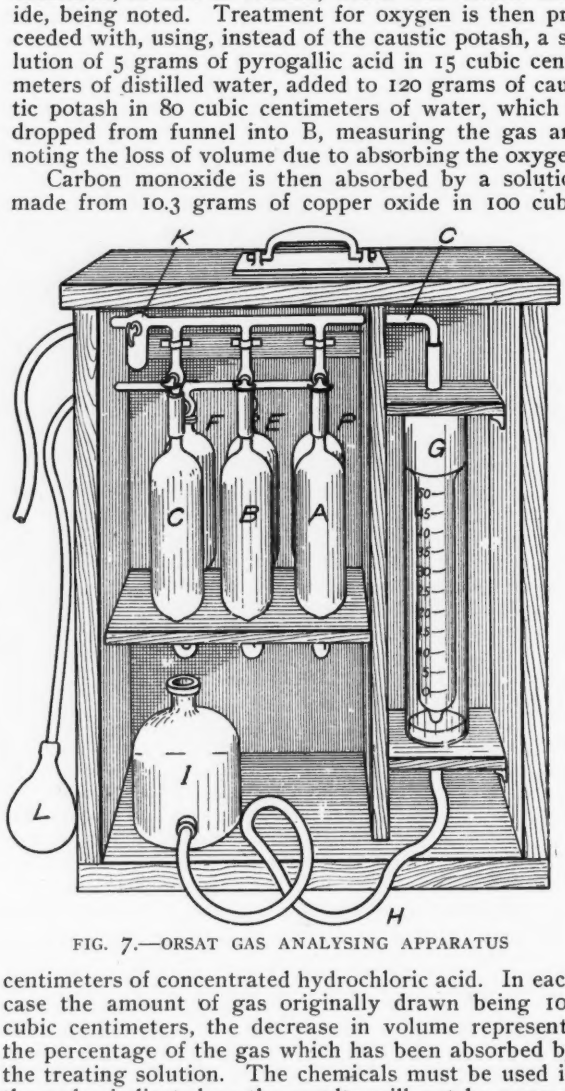


FIG. 7.—ORSAT GAS ANALYSING APPARATUS

centimeters of concentrated hydrochloric acid. In each case the amount of gas originally drawn being 100 cubic centimeters, the decrease in volume represents the percentage of the gas which has been absorbed by the treating solution. The chemicals must be used in the order indicated or the results will not be correct. Care must be taken when passing back and forth and when letting in chemicals that no gas escapes and no air enters the apparatus.

For good combustion the gas should contain from 8 to 10 per cent of carbon dioxide, 10 to 12 per cent of oxygen, and merely a trace, if any, of carbon monoxide. The balance of the flue gas is principally nitrogen and its exact determination is of little consequence after the percentage of the above 3 gases have been ascertained.

Orsat Apparatus

Another form of gas analysis instrument is that devised by Orsat, which is more convenient and requires less time to test a sample of flue gas than does the Eliot apparatus.

This consists of 3 pipettes, A, B, C, which are connected at the top through a stop cock to a common

tube, C, and at the bottom to reagent bottles, P, E, and F, by flexible rubber tubing. A graduated buret or measuring tube, G, is connected at the bottom through the rubber tubing, H, to the pressure bottle, I. The tube, C, connects the measuring tube to the source of the gas supply.

To operate this apparatus the pressure bottle is filled with water and raised until the water level in the measuring tube reaches the connection, C, with the stop cock, K, open. The gas connection is then made and, by lowering the bottle, gas is drawn into the measuring tube until its volume reaches 100 cubic centimeters. With the stop cock, K, closed the gas is then passed into the pipettes, A, B, and C, in the same manner as with the Eliot apparatus, and the volume of the gas noted in each case after treatment. The reagents employed are the same as with Eliot apparatus.

THE HAYS GAS ANALYSIS INSTRUMENT

Wm. B. Pierce Co., Buffalo, N. Y.

There are problems in combustion that can be solved only by flue gas analysis. Reduce the draft a little or do any one of a dozen other things in connection with furnace management and still the question must arise: "Have we moved in the wrong or the right direction?" The evaporation test gives the combined efficiency of the boiler, the furnace, the coal and the fireman.

Does this furnish enough information to enable the engineer to prescribe remedies for faults known to exist somewhere? Obviously there must be some kind of a test that differentiates between the faults that belong to the boiler and the faults that belong to the furnace, the fireman and the coal. It is just as obvious that every judgment upon the furnace must be based upon an inquiry into its gases.

CO_2, the product of complete combustion of coal, is the measure of furnace efficiency. Low CO_2 represents poor furnace conditions. It indicates the presence of excess air, or incomplete combustion and the presence of CO or other combustible gases. The price of low CO_2 is an increase in fuel consumption. In the average plant the loss of fuel due to this one cause is 10 per cent; in extreme cases the loss sums up to 40 per cent.

A flue gas analyzer itself cannot correct furnace conditions. It merely indicates what is wrong and leaves the work of correcting the conditions to the engineer. Nor is it to be supposed that the information desired will always be given by the first test. Excess air may be coming in through holes in the brick work, or through the pores of the bricks themselves, or through holes in the coal bed, or the fault may be due to the regulation of the draft. The cause must be determined by the process of elimination.

The practical use of a flue gas analyzer does not require a knowledge of the chemistry of combustion. Such knowledge is of course highly desirable but by no means necessary to fit one for the work of gas analysis or the intelligent running of a furnace.

In building up furnace efficiency the handiest, most economical and result-producing flue gas analyzer is a small hand instrument that will determine CO_2, O and CO.

The Hays gas analysis instrument is designed for furnace work. Small and compact, simple in construction and operation, complete in itself and requiring no subsidiary laboratory apparatus in order to make a test, accurate and rapid in its determinations, portable and having all its fragile parts spring-suspended to avoid breakage, and adapted for reading in dark corners, this instrument fills a long-felt need.

The gas is determined in the following manner: A sample is measured in the burette A and passed to the absorption pipette B by means of the water level. After the desired absorption has taken place the gas is returned to A and remeasured. The contraction represents the gas that was absorbed. A new reagent is then placed in B to absorb the next constituent which it is desired to determine and the determination made in the same manner. In this manner CO_2, O and CO may be determined.

THE HAYES GAS ANALYSIS INSTRUMENT

THE WESTOVER CO_2 RECORDER

The Caldwell Co., New York, N. Y.

The technical part of the Westover CO_2 recorder is the same as in the hand analyzers used by Hempel, Eliot and Orsat, with the difference that exact mechanism takes the place of the human element.

In the series of events, including the taking of the sample of gas, measuring it, passing it over into contact with the potash solution to the measuring of the residual part of the charge, all are carried out by tooth gear movements so connected and related that no event can take place out of its proper order or turn. These are operated by a small electric motor.

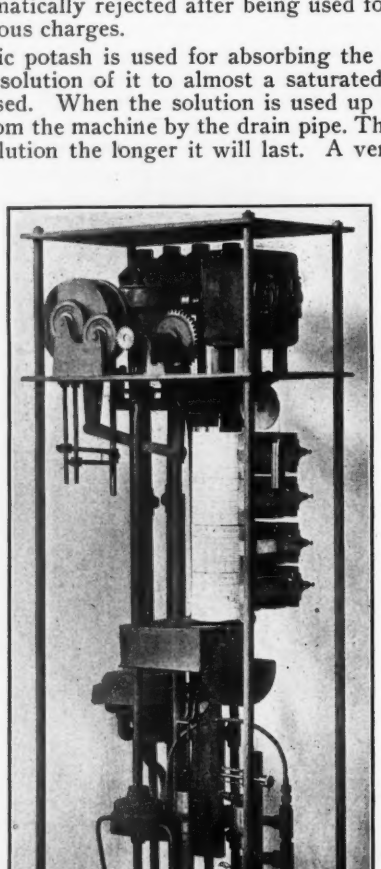
The machine was designed to be in keeping with the other requirements of the engine and boiler room. It is manufactured self-contained, no part being attached to its enclosing case or cabinet.

The records are made by electric contact. The 2 platinum contacts are part of 2 separate floats. When the levels meet, as in the standard Orsat, the electric contacts on the floats come together, closing the electric circuit, this in turn making the record. The instant before the levels meet, the floats not being in contact, every part is perfectly free and no friction is interposed to cause inaccuracy in the records.

To insure each charge being a true sample of the

gas as it existed in the furnace a few seconds before, only 2 measures in 7 are used for analysis, the rest being automatically rejected after being used for driving out previous charges.

Caustic potash is used for absorbing the CO_2 gas, and any solution of it to almost a saturated solution can be used. When the solution is used up it can be drawn from the machine by the drain pipe. The stronger the solution the longer it will last. A very strong



WESTOVER CO_2 RECORDER

solution will attack almost any other material but iron, the caustic potash vessel is, therefore, composed wholly of 1 iron casting with no joints whatever. As the potash solution is not used to measure the percentage of the CO_2 gas, the density of the solution has no bearing on the accuracy of the results, nor is the accuracy of the record affected by moisture in the coal or gas.

THE UEHLING GAS-COMPOSIMETER

Uehling Instrument Co., Passaic, N. J.

The action of the Gas-Composimeter is based on the law governing the flow of gas through 2 small apertures. This law may be illustrated by a simple diadram, Fig. 1, representing 2 chambers C and C^1 which are in communication with each other through the aperture B, and with the source of gas through the aperature A. C^1 is connected with an aspirator D, as shown. The manometers P and Q indicate the gas tension within the respective chambers.

The aspirator set in action, a vacuum is created in chamber C^1, the gas will flow from the chamber C through aperture B to chamber C^1, creating a vacuum in C which will cause gas to enter through aperture A, thus establishing a continuous flow of gas through both apertures.

If a constant vacuum of say 0.48 in. of water be maintained in chamber C^1 and the 2 apertures A and B are of the same size and are maintained at the same

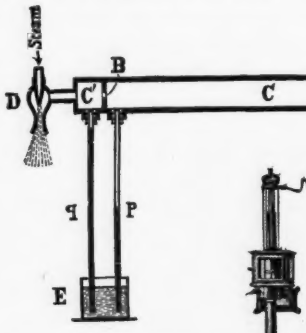


FIG. 1.—PRINCIPLE OF GAS-COMPOSIMETER.

FIG. 2.—THE UEHLING GAS-COMPOSIMETER

temperature, the manometer P will show about one-half the vacuum maintained in C^1 due to the fact that the apertures offer equal resistance to the passage of the gas.

This relation will be maintained so long as the same volume of gas flows through B that enters at A.

If, however, a constituent of gas be continuously taken away or absorbed from the gas in passing through chamber C the vacuum therein will be correspondingly increased.

This increase of vacuum in C, shown by the manometer P, therefore, correctly indicates the volume of gas absorbed and in the Gas-Composimeter is utilized to indicate the percentage of the constituent of the gas to be determined.

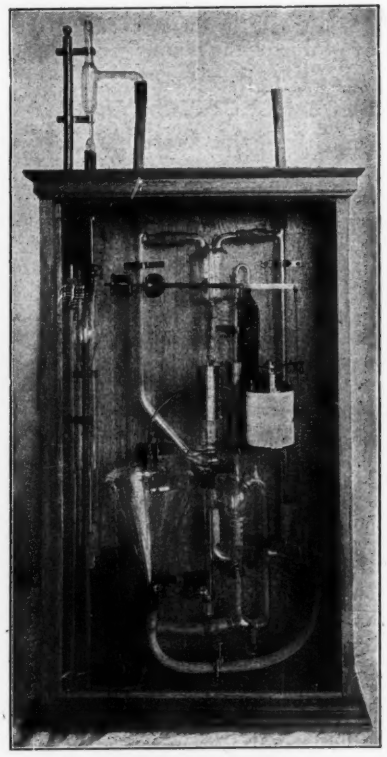
Fig. 2 shows a complete instrument, embodying the above principle in practical form. The Recorder is shown on the left and the observation gauge on the right of the main instrument. The latter is fastened to or near the boiler front, showing the fireman the condition of his fire at all times.

SARCO AUTOMATIC COMBUSTION (CO_2) RECORDER

Sarco Fuel Saving & Engineering Co., New York.

Complete combustion can be detected definitely through a complete flue gas analysis but this requires considerable skill and technical knowledge, and no plan has yet been devised by which this can be done automatically and continuously. The principal part of the analysis, however, is the determination of the percentage of carbon dioxide (CO_2) which shows correctness or incorrectness of furnace operation.

The Sarco automatic combustion (CO_2) recorder gives a continuous record, automatically, of the per-



SARCO AUTOMATIC COMBUSTION CO_2 RECORDER

centage of CO_2 in the gas which is a guide to the operation of furnaces.

The recorder has a gas connection to the flue and a water connection. For the first, gas piping is used and is connected to the last pass of the gases in the boiler. The water connection is made to a small ball-float tank, which is supplied with the recorder. From the tank a fine stream of water passes through the recorder, performing two functions; first, that of pulling the gases through the recorder, and secondly, operating with a siphon discharge the alternate trapping off, determination of CO_2 and expulsion of the gases.

The recorder automatically traps off at regular intervals from a continuous stream of gas, 100 cubic centimeters. This trapped off portion of gas is brought into contact with caustic potash which absorbs the CO_2 and a record is then automatically produced on a chart showing the amount of CO_2 in the respective samples of gas.

Once the recorder is connected up it is only necessary to rewind the clock daily, put on a fresh chart and fill the pen. The level of the caustic solution should be checked daily, as there will be a slight increase in its volume due to the absorption of CO_2. In addition to this it is necessary at intervals of 10 days or 3 weeks, depending upon whether the machine is working 12 or 24 hr. daily, to recharge the caustic potash vessel, which is a simple operation and can be performed easily.

The function of the CO_2 recorder is to provide a record every few minutes of the state of combustion in the boiler furnaces.

TEMPERATURE TESTS

A third method of determining the conditions of combustion in the boiler furnace is by observing the temperature of the gases in the various parts of the furnace, boiler and flues. While it is impossible to obtain ideal temperature owing to imperfect combustion and other influences which affect the temperature of the furnace, this condition can be approached more or less closely and is a standard to seek.

The maximum theoretical temperature obtained by the burning of carbon to carbon-dioxide in dry air may

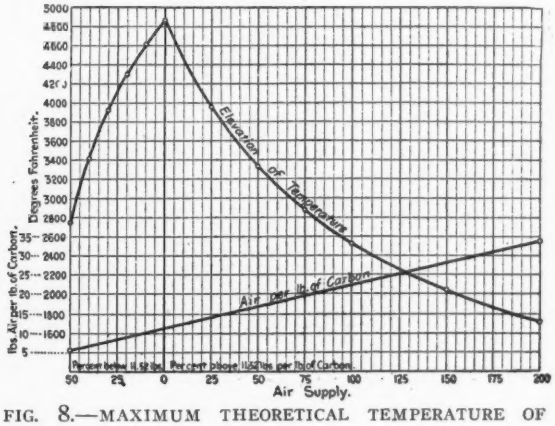


FIG. 8.—MAXIMUM THEORETICAL TEMPERATURE OF A FURNACE

be calculated in the following manner: By calorimeter determination it has been proved that 1 lb. of carbon burned to carbon dioxide generates 14,600 B. t. u.

The products of combustion when burned in dry air will be $3\frac{2}{3}$ lb. $CO_2 + (2\frac{2}{3} \times 3.32 = 8.853)$ lb. nitrogen, making 12.52 lb. of gas. The specific heat of CO_2 is 0.217, that of nitrogen is 0.2438, from which we may obtain the specific heat of the gas which is equal to $(3\frac{2}{3} \times 0.217 + 8.853 \times 0.2438) \div 12.52 = 0.2359$. From this we obtain the elevation of the temperature of the fire above the atmosphere which is $14{,}600 \div 12.52 \times 0.2359 = 4942.5$ deg. F. The temperature of the air being assumed as 60 deg., the temperature of the furnace as calculated would be 5002.5 deg. F.

It will readily be understood that such a temperature as this is never obtained in the furnace but is the theoretical possible limit of temperature which should be striven for. The accompanying diagram shows the maximum theoretical temperature of the furnace gases by the burning of carbon with different quantities of air as calculated in the manner shown above, considering the specific heat of the gases at 0.237, which is the figure commonly taken in temperature calculations.

In practice it is usual to maintain a temperature of about 400 deg. F. in the uptake of the boiler when natural draft is employed upon the furnace. The draft being dependent upon the difference between specific gravity of the gas and that of atmosphere, there is therefore a point in temperature below which the gases

should not fall, as this would mean a light draft and less combustion with other defects which accompany this trouble. When forced draft is employed, the temperature of waste gases can be reduced to about 300 deg. F., as the draft is not dependent upon the weight of the gas and that of atmosphere.

As given by Hiller the temperature which should be maintained in the various parts of the boiler furnace when a Lancashire boiler is employed should be as follows:

Part of Boiler.	Temp. Deg. F.
Boiler furnace	2800
6 ft. behind bridge	1800
Drop flue on end of fire tube	1000
Exit end main flue	650
Base of chimney, minimum	300

For taking these temperatures ordinary mercury thermometers can be employed for all temperatures

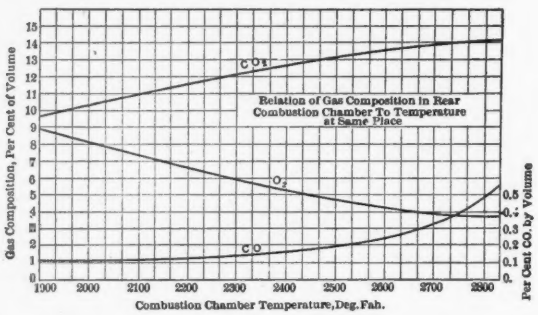

Relation of Gas Composition in Rear Combustion Chamber To Temperature at Same Place
CO2
O2
CO
Gas Composition, Per Cent of Volume
Per Cent CO, by Volume
Combustion Chamber Temperature, Deg. Fah.
1900 2000 2100 2200 2300 2400 2500 2600 2700 2800

FIG. 9.—RELATION OF TEMPERATURE IN FURNACE TO GAS COMPOSITION

under 572 deg. F., and special types of mercury thermometers are able to register up to 980 deg. F. Above this temperature the mercury thermometers are inaccurate and subject the inclosing tube to a dangerously high pressure.

A common method of determining temperatures higher than 1000 deg. is by employing a number of fusible alloys placed in crucibles which are inclosed in a porcelain oven and subjected to the heat of the furnace whose temperature is desired. All alloys whose melting point is below the temperature of the furnace become liquids and by this means, with the proper selection of metals, it is possible to determine, with reasonable limits, the temperature maintained in the furnace, as metals or alloys can be secured whose melting points are not far apart.

The water pyrometer is another apparatus for determining high temperatures. This consists of a block of iron or other metal of known weight which is subjected to the heat of the furnace for a sufficient time to be raised to the temperature of the gases, and is then dropped into a vessel containing a known quantity of water, the temperature of which is determined before and after the heated metal has been dropped into it. To determine the temperature of the furnace subtract the original temperature of the water from the highest temperature it attains, multiply this difference by the weight of the water plus the water equivalent of the cup; divide this product by the weight of the iron block times its specific heat; to the quotient is added the highest temperature reached by the water; the result will be the temperature of the furnace. The water equivalent of the cup is obtained by multiplying its weight by the specific heat of the metal of which it is made.*

Air pyrometers are of 2 classes; one maintains a constant volume with varying pressure, and the other a constant pressure with a varying volume. These pyrometers are arranged with tubes and graduated scales which read directly the temperature to which the bulb is subjected. The air is contained in a porcelain bulb of known volume, and the connecting tubes to the indicating scales are made of very small diameter and convenient length.

Electrical pyrometers are either of the thermo-couple type or depend upon change in conductivity of some metal wire. The indicating devices used with electrical pyrometers are in fact milivoltmeters which are calibrated to read the degree of heat instead of the electromotive force of the couple.

BRISTOL ELECTRIC PYROMETERS

The Bristol Co., Waterbury, Conn.

A novel and valuable feature of the Bristol quick reading electric pyrometer shown in the illustration is that the fire end or thermo-couple is constructed in the patented form illustrated by diagram and has the platinum rhodium tip of couple exposed directly to furnace gases, the temperature of which this fine tip quickly assumes. It will be noted that the cold end of the fire end is provided with a handle and that from the opposite end which is inserted into the furnace the fine tip of the thermo-couple projects. Figure 2 shows the couple ready to measure the temperature. The illustration Fig. 1 shows the same fire end with the protecting sheath of iron pipe pushed out over the tip of couple in the position it should have while being inserted into the furnace.

As soon as the fire end has been inserted into the furnace the protecting sheath is drawn back exposing the tip to the hot furnace gases and a reading of the temperature at the tip can then be taken from the portable instrument within a few seconds. After a reading has been taken the fire end should be withdrawn and partially cooled before another reading is taken.

The construction of this form of quick reading thermo-couple for use with the Bristol portable electric pyrometers can best be explained from diagram, Fig. 3. A is the junction of platinum rhodium elements which begin at the points B and C. These platinum rhodium elements are made long enough so that the junctions B and C can be protected continuously inside of the tubes shown in Fig. 2. The section of the thermo-couple from B and C to D consists of special alloys of such characteristics that the thermo-electric effects at the junctions B and C balance each other for temperatures up to 1,200 deg. F. It will readily be seen that even when the tip of couple A is heated to a high temperature by quick exposure to furnace gases the junctions B and C can be so protected that their temperatures will not exceed 1,000 deg. F. during the few seconds the tip is exposed in the furnace.

The portable indicating instrument shown in Fig. 2 is equipped with a Weston Electrical movement

*Expressed as a formula this becomes $T = t' + \frac{P\,(t'-t°)}{pc}$ where T is the desired temperature, t' is the highest temperature reached by the water, P is the weight of the water plus the water equivalent of the cup, t° is the original temperature of the water, p is the weight of the iron block and c is the specific heat of the iron.

with pivot-jewel bearings, the practical features of which are widely known.

After the combustion gases have left the fire box of a boiler furnace it is desirable to measure their temperatures at a number of other points where the temperature is lower. These lower temperatures in the flues and stack can be continuously measured by means of the regular special alloy fire ends furnished with Bristol pyrometers for temperatures lower than 2,000 deg. F.

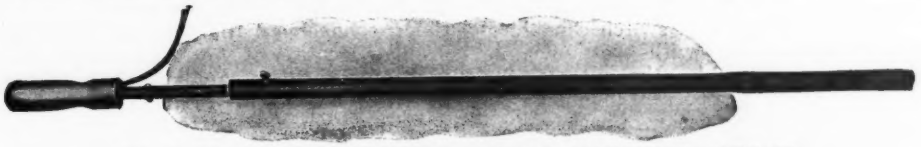


FIG. 1.—THE BRISTOL PYROMETER READY TO INSERT INTO FURNACE

FIG. 2.—BRISTOL PYROMETER WITH TIP EXPOSED FOR TAKING READING

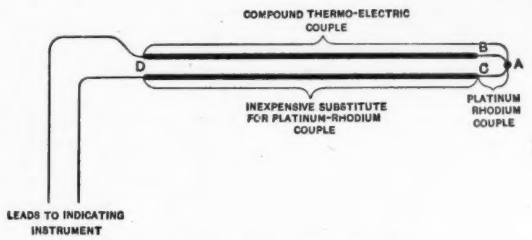


FIG. 3.—DIAGRAM SHOWING CONSTRUCTION

HOSKINS PYROMETERS

Hoskins Mfg. Co., Detroit, Mich.

Pyrometers made by this company depend for their action upon the generation of a thermo-electric current. They are capable of being used with accurate results within the range of temperature between 570 and 2550 deg. F.

The type A meter is a compact, durable and portable instrument; the moving part is surrounded by a thin iron case and the whole enclosed in an 8 by 3.5 in. quartered oak box which is fitted with a leather grip handle. The readings given are dead beat and may be taken with the meter held on the arm.

Fahrenheit scales, direct reading in 25-deg. divisions, are placed in all meters unless otherwise ordered.

The type C meter is a wall instrument, mounted in a heavy iron case suitable for permanent installations. This meter has a ground glass dial, illuminated from the rear by 2 incandescent lamps. The indicating scale is 13 in. long, which permits of taking readings at a considerable distance.

For a short length from the hot end the elements of the couple are left bare, the remaining part being covered with an asbestos winding which electrically insulates the elements above the welded joint. The other, or cold end, of the couple terminates in a special attachment contained in a handle. The standard couple, consists of ⅛-in. square section elements, 36 in. long, complete with attachment and handle.

The standard equipment of leads consists of 20 ft. of flexible copper, rubber-insulated, 2-conductor cord. It is to be particularly noted in this connection that the meter is calibrated for a definite external resistance, thermo-couple and leads, and therefore, these must not be altered in any detail, else the accuracy of the readings will be impaired.

The hot end of the thermo-couple is inserted into the furnace chamber of which the temperature is desired. Any difference in temperature of this chamber from that of the cold end of the couple will generate an electro-motive force in the latter, proportional to the temperature difference between the 2 ends of the couple and causes movement of the pointer over the scale of the meter.

HOSKINS PYROMETER EQUIPMENT COMPLETE

The alloyed metals, of which the thermo-couple is composed, have a remarkable resistance to oxidation at temperatures below their melting point, are unaffected by ordinary furnace gases and do not readily alloy with other metals such as aluminum and its alloys, brass, copper or lead. They are so constituted that the couple may safely be dipped directly

into any of these metals in the molten state for a sufficient length of time to take a temperature reading.

For purposes of indicating on one instrument the temperature from a number of points, as for instance, from each of a battery of furnaces, a thermo-couple is fixed in place at each desired point and from these, leads are run to a central selective switch capable of connecting any desired couple with the indicating meter. This arrangement enables the operator, by merely turning the switch, to observe, in quick succession, the temperatures of the various furnaces.

STEEL CAPILLARY TUBE THERMOMETER

The Schaeffer & Budenberg Co., Brooklyn, N. Y.

The importance of knowing the temperature of flue gases is thoroughly appreciated, but the testing of temperatures is not practiced as much as it might be. This is due to quite an extent to the fact that instruments heretofore put on the market for that purpose were of the ordinary high range thermometer type, which are difficult to read, and besides are easily broken.

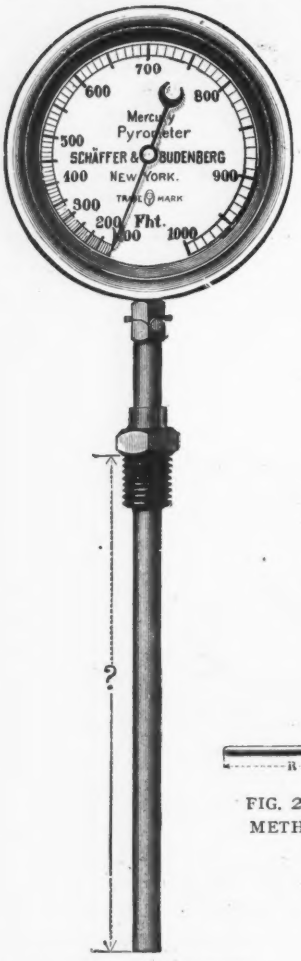


FIG. 1.—CAPILLARY TUBE MERCURY THERMOMETER

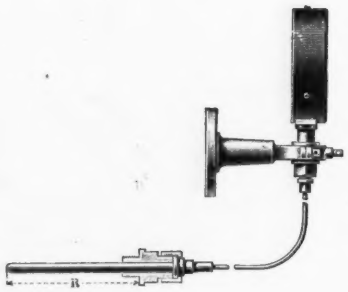


FIG. 2.—SIDE VIEW SHOWING METHOD OF USING MERCURY THERMOMETER

The steel capillary tube thermometer, while as sensitive and quick-acting as an ordinary mercury thermometer, has the great advantage of being easily read, owing to the large dial arrangement and temperatures as high as 1,000 deg. F. are accurately indicated by it.

This can be read from a distance, and the tube containing the mercury being made of steel instead of glass the instrument is very strong and durable and should therefore become more common in use.

The taking of temperatures of flue gases is many times connected with great difficulty owing to the peculiar location of the flue openings where tests are to be made. The capillary tube thermometers may be fitted with flexible stem of any desired length, thus enabling the engineer to place the instrument at a convenient point for observation.

ELECTRICAL THERMOMETRY

Taylor Instrument Co., Rochester, N. Y.

The Fery radiation pyrometer is based upon the principle that radiation, which emanates from a hot body or which passes out through an observation hole in the wall of the furnace or flue can be focused by a concave mirror, and the heat thus focused, measured by a thermo-couple. In this instrument, at the focus, is placed one junction of a thermo-couple, whose temperature is raised by the radiated heat falling upon it; the hotter the furnace the greater the rise of temperature of the junction.

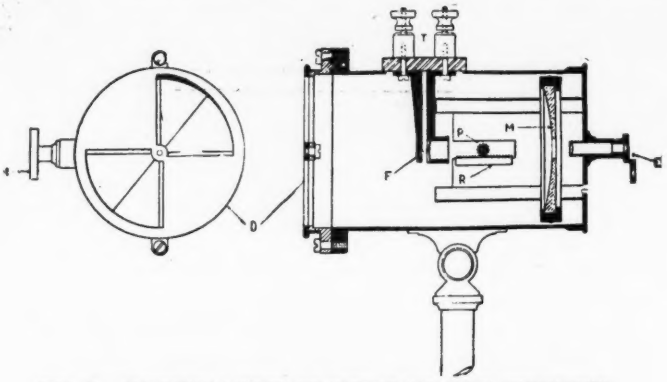


FIG. I.—SECTIONAL VIEW OF FERY RADIATION PYROMETER

By reference to the illustration it will be seen that this radiation pyrometer is virtually a reflecting telescope having at a point, F, on its axis one junction of a copper-constantan thermo-couple. On this junction the radiated heat of the hot body under examination is focused by the concave mirror, M. The 2 junctions of the thermo-couple are situated quite close together so that they partake equally in any changes of atmospheric temperature, but the cold or comparison junction is screened from the reflection focused by the mirror. To prevent overheating of the thermo-couple when the telescope is sighted on a very hot body, the diaphragm D, is provided which can be swung over the mouth of the telescope thus reducing the effective area, and consequently the radiated heat falling upon the mirror.

As a guide for pointing the telescope, the eye piece E, is provided at the rear through which can be seen a reflected image of the hot body. The focusing is done by means of a milled head, H, at the side of the telescope and its accuracy verified by observing the reflected image of the hot body.

Two scales are placed upon the indicating pyrometer, one for reading temperatures ranging from 1,000 to 2,400 deg. F., and the second from 1,800 to 3,600 deg. F. This instrument is arranged to fold up

and drop into a box making it easily carried from place to place.

In the recording outfit, the telescope is generally permanently fixed in position upon a steady support. As it is not usually convenient to have a hole in the furnace wall permanently open, the telescope is then

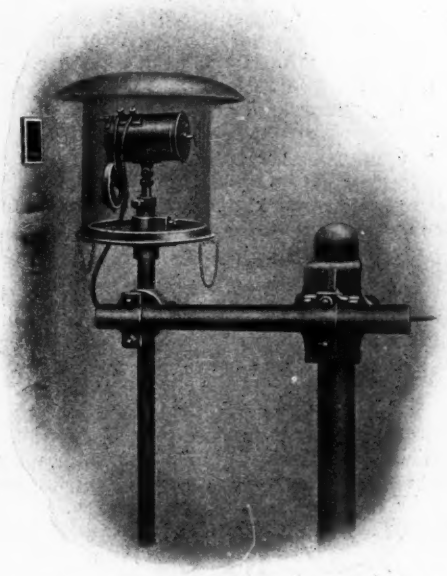
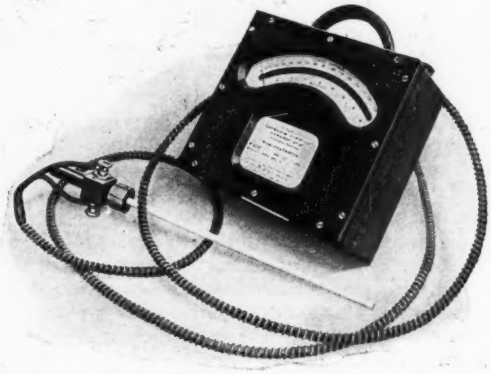


FIG. 2.—RADIATION PYROMETER IN OUT DOOR SERVICE

sighted into a closed fire-clay tube which projects well into the furnace and with a great length compared to its diameter. The records are made by a thread recorder which is connected by a twin cable to the thermo-couple in the telescope.

These pyrometers, as will be noted from the scale provided for them, are used where the temperature ranges from 1,500 to 3,600 deg. F. For lower temperatures ranging up to 2,500 deg. F., the platinum, platinum-rhodium couple is found more convenient and less expensive.



.FIG. 3.—THERMO-ELECTRIC THERMOMETER OUTFIT

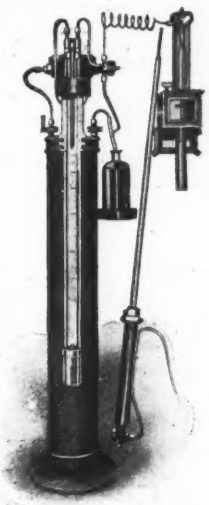
For high temperature measurements in industrial work it is usually sufficient if the cold junction in the thermo-couple head is kept thoroughly cool in the air outside the furnace and this consideration decides the length of the couple. The heads of all these thermo-electric thermometers are so constructed that a mercury thermometer can be inserted to ascertain the actual mean temperature under working conditions, and the pointer of the indicator or recorder should indicate this temperature when not attached to any circuit.

For measuring still lower temperatures ranging up to 1,600 deg. F., the platinum resistance thermometer is one which has met with considerable success in the power plant. It measures temperatures by the consequent change in resistance of the platinum wire, the sensitive portion of the thermometer being a fine platinum wire, wound on a frame of mica, and usually arranged and kept in a small space. This fine wire is connected by means of stouter wires to the terminals on the right of the thermometer.

THE UEHLING PNEUMATIC PYROMETER

Uehling Instrument Co., Passaic, N. J.

The Uehling pneumatic pyrometer is a practical, simple and convenient adaptation of the well known and tried laws governing the thermometric properties of air, which forms the only moving part or element of the instrument. While it is sensitive to every variation in temperature, it is at the same time designed and built for everyday service in the factory, power plant, iron and steel works, as well as for laboratory purposes.



THE UEHLING PNEUMATIC PYROMETER

Single unit and multiple systems are built and calibrated over any desired range of temperature up to 3,000 deg. F., or in degrees Centigrade if preferred. The cut illustrates a single unit pyrometer with recorder and portable type fire tube, which is connected to the main instrument by flexible tubing. The style and size of fire tube, and the length of connecting tubing are determined by local conditions.

In addition to the pyrometer and recorder, one or more auxiliary indicators may be employed, which can be placed at any point most convenient to the operator who is responsible for the temperature regulation.

ONE-HALF OUNCE oxalic acid to a pint of soft water gives one of the best means of cleaning and brightening brass work.

WHEN THE WORLD seems to be against you, you have met it the wrong way. Change yourself and the world will be your friend.

FUELS

THEIR COMPOSITION AND CLASSIFICATION

COMBUSTION as already explained is a process of chemical combination, and in our ordinary use of the word we refer to a combination of some other element with oxygen. The word fuels is therefore used to signify those materials which are capable of combining with oxygen in the ordinary furnace. The chief constituent of all such fuels is carbon, although hydrogen and sulphur may form a small portion and take part in the combustion process.

TABLE I.—HEAT VALUE OF VARIOUS FUELS, AND COMPOSITION

Name of Combustible.	Composition.				Calorific Power.
	C	H	Volatile Matter.	Ash	
Carbon	1.00	....	....	....	14,400
Anthracite coal	0.90	0.03	0.03	0.01	13,500
Bituminous coal	0.85	0.05	0.06	0.06	14,400
Lignite	0.70	0.05	0.20	0.05	11,700
Peat	0.55	0.05	0.30	0.10	9,000
Peat 0.20 water	0.39	0.04	0.50	0.07	7,200
Coke	0.85	0.05	....	0.10	12,600
Peat-charcoal	0.82	....	....	0.18	9,000
Dry wood	0.48	0.06	0.05	0.01	7,200
Wood 0.20 water	0.40	0.05	0.25	0.01	5,400
Wood-charcoal	0.80	....	0.04	0.07	10,800
Hydrogen	....	1.00	....	....	62,000
Carbonic oxide	0.43	...	0.57	....	4,320
Illuminating-gas	0.62	0.21	0.17	....	18,000
Gas from blast-furnace	0.06	0.02	0.92	....	1,620

Division of fuels falls naturally into the headings, wood, peat, gas in its different varieties of natural, producer and blast furnace, oils, coals, and artificial fuels such as coke and briquettes. Practically all of these come from the stores accumulated during the process of ages, wood and peat being the only ones which are in process of making in any considerable quantities, at the present time.

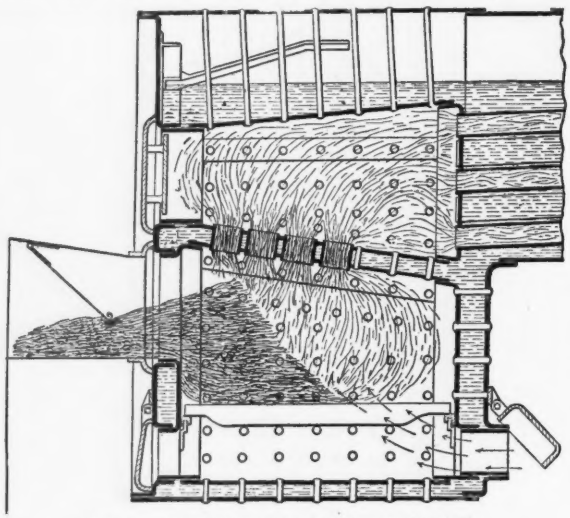


FIG. 1.—FURNACE FOR BURNING STRAW

While wood varies according to varieties as to its composition and heating value this variation being shown by the figures in Table II, its heat value as compared with other forms of fuel is so slightly variable that it is usual to consider wood as "just wood," without regard to the kind. Taking it in this way it is usually considered that 2.5 lb. of dry wood are equal to a pound of average soft coal, and that measuring in bulk, a ton of Cumberland coal of the best quality is equal to 2.12 cords of wood.

Forms of fuel which approach to wood in composition and are used in certain sections to a considerable extent are straw, tan bark, and bagasse. The value of straw is shown in Table II.

Bagasse

The cane is treated in two different ways. In the first it is chopped into small pieces and soaked in water to take out the sugar, called the diffusion process; in the 2d it is crushed by cane rolls, which squeeze out the juice, and is therefore called mill bagasse. The diffusion process is largely used in the tropics, and Table III shows the composition of such material. Table IV shows the value of 1 pound of mill bagasse at the different degrees of extraction. Figuring on the basis that a pound of clear fibre has a heat of 8325 B. t. u., a pound of molasses 6956 B. t. u. and a pound of sugar 7223 B. t. u.

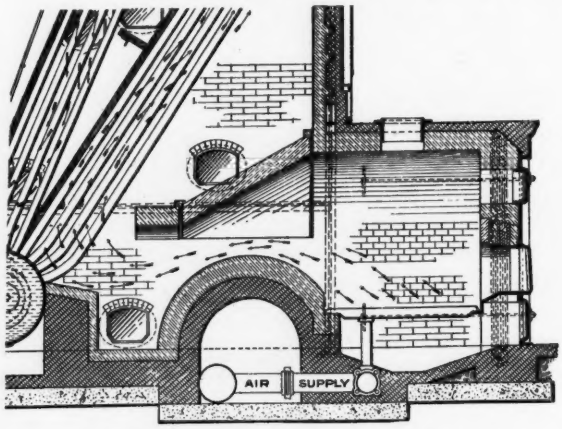


FIG. 2.—THE STIRLING BAGASSE FURNACE

In his book on Steam Boiler Practice, W. B. Snow says that the useful part of bagasse consists of woody fibre, and with this is mixed water in varying degrees, and some other combustible salts. For tropical canes the bagasse or refuse constitutes about 12 per cent of the original cane, while for Louisiana cane 10 per cent is the average value. The heat value depends upon the water content, as this must be evaporated by the heat in the fuel, and the water content in turn depends upon the method of extracting used in the making sugar.

For dry Louisiana bagasse the composition is about as follows: Volatile matter 81.37 per cent, fixed carbon 14.27 per cent, ash 4.6 per cent. In the original cane the fibre is about 10 per cent of the total, and some 75 per cent is water. In the process of extraction, from 40 to 80 per cent of the cane is taken away as juice and when 75 per cent is removed the remaind-

er will be composed of about 51 per cent water, 40 per cent fibre, 6 per cent sugar, and 3 per cent molasses.

A pound of press bagasse will develop altogether 3972 B. t. u., but of this 611 B. t. u. will be used in evaporating the contained water leaving as available 3,361 B. t. u.; 4.25 lb. of cane bagasse will then be required to equal 1 lb. of coal which has a heat value of 14,000 B. t. u., and each ton of cane will yield bagasse equivalent to about 120 lb. of coal.

The heat value of bagasse depends upon the proportions of fiber, molasses, sugar and water left after the extraction. The heat furnished by the different constituents is about as follows: Fiber, 8325 B. t. u. per lb.; sugar, 7223 B. t. u.; molasses 6956 B. t. u. per lb. The water, of course, takes up heat units instead of furnishing any. To get, therefore, the heat value of a pound of bagasse multiply the heat value of fiber by the per cent fiber in the bagasse, the heat value of sugar by the per cent sugar and the heat value of molasses by the per cent of molasses. The sum of these 3 products gives the total heat produced by a pound of the fuel. From this must be subtracted the heat units required to evaporate the moisture and the remainder will be the net heat available.

For air supply, practice shows that with forced draft about 200 cu. ft. are needed per pound of fuel and with ordinary draft 270 cu. ft. The forced draft has the additional advantage that since the air is under pressure smaller flues and stack can be used and the air and gases are more intimately mingled. The pressure used with forced draft is never more than 2 oz. per sq. in., equal to about 3.5 in. water column, and more commonly 1 to 1.25 oz. is found sufficient. The large amount of moisture in the fuel calls for larger flues and stacks than is the case with coal, and the furnace should be so arranged that there will be no pressure in the furnace proper or it may force gases and smoke back into the boiler room. Under proper conditions a pound of green bagasse should evaporate from 2 to 2.25 lb. of water from a feed temperature of 100 deg. and at 90 lb. steam pressure. The top of the

TABLE II.—COMPOSITION AND PROPERTIES OF WOODS

KINDS	WEIGHT PER CU. FT. LB.	WEIGHT PER CORD LB.	EQUIV. WT. OF COAL 13500 B.T.U.	CARBON %	HYDROGEN %	OXYGEN %	NITROGEN %	ASH %	B.T.U. PER LB.	AUTHORITY
APPLE	49	3140	1260						5420	HUTTON
ASH	46	3520	1420						5450	"
BEECH	43	3250	1300	49.36	6.01	42.69	0.91	1.06	5400	SHARPLESS
BIRCH	45	2880	1190	50.20	6.20	41.62	1.15	0.81	5580	HUTTON
CHERRY	42	3140	1260						5420	"
CHESTNUT	41	2350	940						5400	SHARPLESS
ELM	35	2350	940						5400	"
HEMLOCK	25	1220	580						6410	HUTTON
HICKORY	53	4500	1800						5400	SHARPLESS
MAPLE HARD	49	3310	1340						5460	HUTTON
OAK LIVE	59	3850	1560						5460	"
" WHITE	52	3850	1540	49.64	5.92	41.16	1.29	1.97	5400	RANKINE
" RED	45	3310	1340						5460	HUTTON
PINE WHITE	25	1920	970						6830	"
" YELLOW	36	2130	1050						6660	"
POPLAR	36	2130	1050	49.37	6.21	41.60	0.96	1.86	6660	"
SPRUCE	25	1920	970						6830	"
WALNUT	35	3310	1340						5460	"
WILLOW	25	1920	970	49.96	5.96	39.56	0.96	3.37	6830	RANKINE
		AVERAGE		49.70	6.06	41.30	1.05	1.80		
STRAW	COMPRESSED		WATER							
WHEAT			16.00	35.86	5.01	37.68	0.45	5.00		CLARK
BARLEY	6-8LB.		15.50	36.27	5.07	38.26	0.40	4.50		"
	AVERAGE		15.75	36.06	5.04	37.97	0.42	4.75	5155	

TABLE III.—COMPOSITION OF BAGASSE AND CANE

COMPONENTS	CANE	75% EXTRACTION BAGASSE	
		IN % OF CANE	IN % OF BAGASSE
WOODY FIBER	10	10.	40
WATER	75	12.75	51
SUGAR	9	1.5	6
MOLASSES	6	.75	3
	100	25.00	100

TABLE IV.—HEAT VALUES OF BAGASSE AND VARIATION WITH DEGREE OF EXTRACTION

Per cent Extraction on Weight of Cane.	Per cent Moisture in Bagasse.	Fiber.		Sugar.		Molasses.		Total Heat developed. B. T. U.	Heat required to evaporate Moisture present. B. T. U.	Heat Available. B. T. U.	Pounds Bagasse required to equal 1 lb. of Coal. Heat Value 14,000 B. T. U. Calculated.	Cu. ft equivalent per Ton of Cane. Pounds.	Temperature of Fire. Fahr.
		Per cent. in Bagasse.	Fuel Value. B. T. U.	Per cent. in Bagasse.	Fuel Value. B. T. U.	Per cent. in Bagasse.	Fuel Value. B. T. U.						
90	0.00	100.00	8,325	—	—	—	—	8,325	—	8,325	1.68	119	2,465°
85	28.33	66.67	5,550	3.33	240	1.67	116	5,900	339	5,561	2.52	119	2,236
80	42.50	50.00	4,162	5.00	361	2.50	174	4,697	509	4,188	3.34	120	2,023
75	51.00	40.00	3,330	6.00	433	3.00	209	3,972	611	3,361	4.17	120	1,862
70	56.67	33.33	2,775	6.67	482	3.33	232	3,489	679	2,810	4.98	120	1,732
65	60.71	28.57	2,378	7.15	516	3.57	248	3,142	727	2,415	5.80	121	1,612
60	63.75	25.00	2,081	7.50	541	3.75	261	2,883	764	2,119	6.61	121	1,513
55	66.12	22.22	1,850	7.78	562	3.88	270	2,682	792	1,890	7.40	121	1,427
50	68.00	20.00	1,665	8.00	578	4.00	278	2,521	815	1,706	8.21	122	1,350
45	69.55	18.18	1,513	8.18	591	4.09	284	2,388	833	1,555	9.00	122	1,284
40	70.83	16.67	1,388	8.33	601	4.17	290	2,279	849	1,430	9.79	123	1,222
25	73.67	13.33	1,110	8.67	626	4.33	301	2,037	883	1,154	12.13	124	1,077
15	75.00	11.77	980	8.82	637	4.41	307	1,924	899	1,025	13.66	124	1,002
0	76.50	10.00	832	9.00	650	4.50	313	1,795	916	879	15.93	126	906

smoke stack should never be less than 120 ft. above the grate and if the arrangement of flues and tubes is such as to produce any considerable friction a greater height should be used.

As to grate area required, natural draft furnaces will run about 1 sq. ft. of grate for each 165 lb. of water evaporated per hour, while forced draft furnaces will work well with 1 sq. ft. of grate to 540 lb. of water per hour.

Two systems of burning bagasse are used, that with a hearth and the grate system, where the furnace is much like that for burning any other fuel, only that

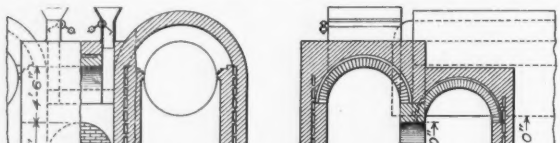


FIG. 3.—THE MYERS FURNACE FOR BURNING BAGASSE OR TAN BARK

the fuel chamber is much larger. Different arrangements of furnaces are used, some of the grates being horizontal, others, inclined, still others having step grates. Hearth furnaces must always be supplied with forced draft.

A type of bagasse furnace furnished with the Stirling boiler is shown in Fig. 2, and a furnace which is equally well adapted for either bagasse or tan bark is shown in Fig. 3, this being the invention of David M. Myers, of New York City.

Tan Bark

Tan bark is usually quite moist, containing a certain per cent of water, and in this condition has a heat value of 4284 B. t. u. per pound. If perfectly dry and containing as is common, 15 per cent of ash, its heating power will be 6100 B. t. u. per pound. When burning it wet, as in the case of all moist fuels, the tan bark must be kept surrounded by heated surfaces, and sufficient fuel which has already been dried and is

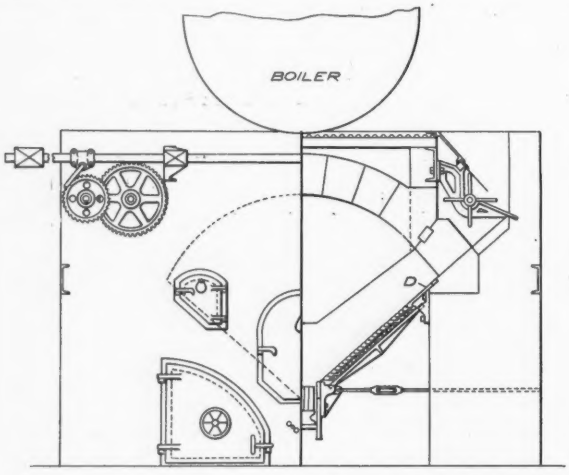


FIG. 5.—FURNACE FOR TAN BARK REFUSE

burning kept in the furnace to insure the drying out of the fresh fuel as thrown on the fire.

The amount of moisture in the tank bark varies with the leaching process used, and usually runs from 62 to 70 per cent. It will average around 65 per cent, so that 100 lb. of air dried bark sent to the mills will produce in the boiler room 213 lb. of spent tan. A pound of the fuel when dry will have a heat value of 3325 B. t. u. per pound, and of this 660 B. t. u. will be required to evaporate the moisture, leaving 2665 B. t. u. as the available heat from each pound of fuel fired

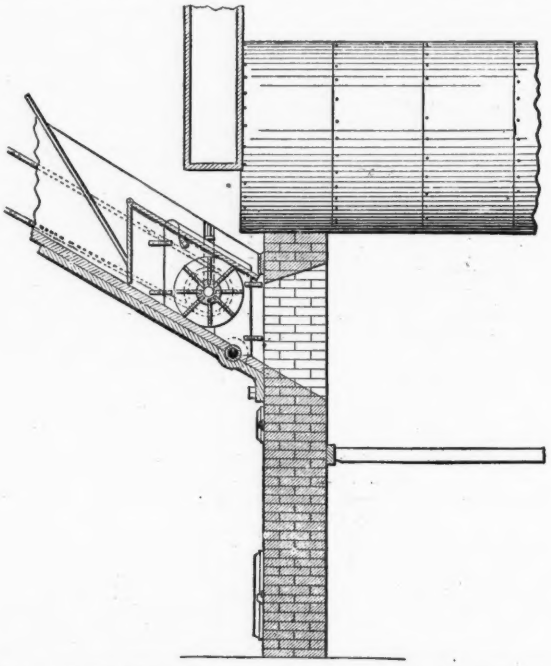
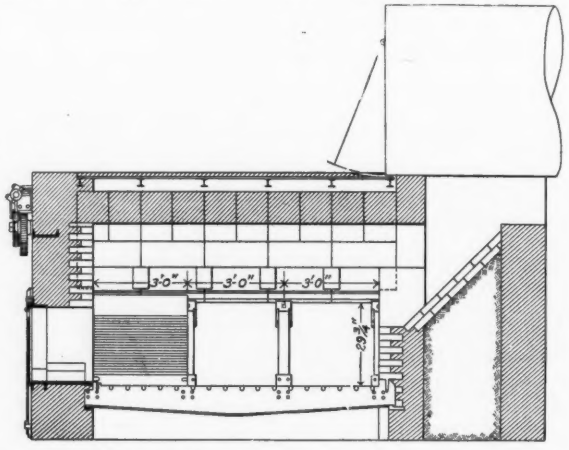


FIG. 4.—THE STILLMAN TAN BARK AND BAGASSE FURNACE

under the boiler. This makes the heat value of a pound of dry tan bark 5676 B. t. u., or about 0.42 lb. of coal having a heat value of 13,500 B. t. u.

In chemical composition the dry tan will have about 1.42 per cent mineral ash, 6.04 per cent of hydrogen, 51.8 per cent of carbon, and 40.74 per cent of oxygen.

Much of the data following is from a paper by David M. Myers on Tan Bark as Fuel.



Test of boilers fired with tan bark show an equivalent evaporation from and at 212 deg. per pound of tan as fired of 1.48 lb. of water, when using an ordinary furnace, and 1.93 lb. water, when using a furnace

specially designed for the burning of tan, and with an automatic continuous feeding stoker.

For using tan bark under the boiler the furnace ordinarily is of the Dutch oven type, set in front of the boiler, and fired from the top through feed holes, a typical furnace having 2 rows of firing eyes, with 3 eyes each, and 2 eyes on the same side of the furnace usually fired at a time. The perpendicular distance from the grate surface to the highest point of the arch inside, was 48 in. and the ratio of heating surface to grate surface 26.3 to 1, the furnace having 79.3 sq. ft. of grate area.

Experiments made on the burning of tan show that when the tan is pressed to remove moisture and decrease the bulk, the thermal efficiency of the boiler is increased from 60 to about 63 per cent, and the capacity of the boiler is increased by some 20 per cent. In order to burn only the same weight of combustible material with the pressed tan, it is necessary to reduce the amount of grate surface. The draft required is in the neighborhood of 0.45 in. between boiler and damper, by the water gage, and mixing a percentage of coal with the tan much increases the efficiency and capacity of the outfit.

As in the case of other fuels the method of firing has much to do with the boiler capacity developed, and also the efficiency of the boiler. The spent tan weighs about 33 lb. to the cubic foot, and when using a mixture of 1 lb. coal to 6 lb. of pressed tan the boiler efficiency was increased 4 per cent, the percentage of carbon dioxide in the flue gases 3 per cent, and the rated capacity of the boiler 40 per cent.

In proportioning grates for a tan bark furnace, the grate surface often allowed is about 3.25 boiler hp. per square foot of grate surface. The grates usually have from 20 to 30 per cent air space, with an actual opening between bars of 3/16 to ¼ in. Smaller spaces do not give enough air area, and larger spaces permit the tan to fall through into the ash pit. As the percentage of ash is so small, a shaking grate is hardly needed, where tan alone is burned, as no clinker will be formed and in some cases fires need be cleaned only once in 12 hr. The fire should be shaken or disturbed very little.

When feeding through the holes in the top of the furnace arch, the tops of the cones of tan, directly beneath the firing eyes, vary from 2 to 5 ft. above the grate surface, and the depth where the cones meet will be from 6 to 18 in., depending on the fire.

The angle of the slide is about 55 deg. to the horizontal on the open floor, and inside a hot furnace this is about 45 deg. When set on a sloping grate the angle of the slide is 39 to 41 deg., which angles have been used in designing automatic tan furnaces. In one furnace designed by D. M. Meyers, of New York City, large combustion space was provided above the burning fuel, the grates were oppositely inclined, converging downward to a set of shaking and dumping grates at the bottom, the fuel was automatically stoked, by means of rotating comb shafts, the fuel was dried on dead plates over which the fuel passed before it received any air supply; concentrated draft from the opposing grate surfaces gave a center of combustion under the center of the boiler, and the arch of the furnace was so shaped as to direct the flames back upon the dead plate.

The results of tests made on a boiler with this furnace showed decided advantages over the ordinary form.

There is considerable difference between oak tan and hemlock tan in value. The oak tan as ordinarily burned, giving about 2.08 horse-power per square foot of grate, and the hemlock tan 1.5 horse-power.

TABLE V.—COMPOSITION OF DIFFERENT GASES FROM GEBHART AND PARSONS

	H	CO	CH_4	C_2H_4	O	CO_2	N	CU. FT. OF AIR PER CU. FT. OF GAS	B.T.U. PER CU. FT. OF GAS. HIGH	B.T.U. PER CU. FT. OF GAS. LOW
NATURAL GAS	1.7	0.55	94.16	0.30	0.30	0.29	2.80	9.13	989	888
CANNEL—COAL GAS	27.7	6.8	50.0	13.0		0.1	2.4	6.50	843	762
COMMON—COAL GAS	39.78	7.04	45.16	6.38	0.06	1.08	0.50	6.38	727	651
CARBURETTED WATER GAS	21.8	28.1	30.7	12.9	0.5	3.8	2.2	6.00	702	635
UNCARBURETTED WATER GAS	49.50	35.93	1.05			4.25	8.75	2.10	295	265
PRODUCER-GAS, LITTLE STEAM	9.2	25.3	3.1	0.8		3.4	58.2	1.24	160	150
LOOMIS PETTIBONE COAL GAS	14.0	20.0	2.0	0.20	0.10	8.2	55.5			
DOWSON GAS, AVERAGE	18.0	25.0	3.0			7.0	47.0	1.32	119	115
TAYLOR GAS, "	21.0	18.0	2.0		3.0	6.0	57.0	0.93	130	116
MOND "	29.0	12.0	2.0			14.5	42.5	1.17	156	139
COKE OVEN GAS	53.0	6.0	35.0	2.0		2.0	2.0	5.06	620	584
BLAST FURNACE GAS	3.0	27.5				10.0	59.4	.81	100	99

Kind of Gas.	No. of Heat-units in 1000 Cubic Feet Used.	No. of Heat-units in Furnaces after Deducting 25% Loss.	Average Cost per 1000 Cubic Feet.	Cost of 1,000,000 Heat-units Obtained in Furnaces.
Natural gas	1,000,000	750,000		
Coal-gas, 20 candle-power	675,000	506,250	$1.25	$2.46
Carburetted water-gas	646,000	484,500	1.00	2.06
Gasoline-gas, 20 candle-power	690,000	517,500	0.90	1.73
Water-gas from coke	313,000	234,750	0.40	1.70
Water-gas from bituminous coal	377,000	282,750	0.45	1.59
Water-gas and producer-gas mixed	185,000	138,750	0.20	1.44
Producer-gas	150,000	112,500	0.15	1.33
Naphtha-gas, fuel 2½ gals. per 1000 ft.	306,365	229,774	0.15	0.65
Coal $4 per ton, per 1,000,000 heat-units utilized				0.73
Crude petroleum, 3 cents per gallon, per 1,000,000 heat-units				0.73

	Natural Gas.	Coal-gas.	Water-gas.	Producer-gas. Anthracite.	Producer-gas. Bituminous.
CO	0.50	6.0	45.0	27.0	27.0
H	2.18	46.0	45.0	12.0	12.0
CH_4	92.60	40.0	2.0	1.2	2.5
C_2H_4	0.31	4.0			0.4
CO_2	0.26	0.5	4.0	2.5	2.5
N	3.61	1.5	2.0	57.0	56.2
O	0.34	0.5	0.5	0.3	0.3
Vapor		1.5	1.5		
Weight in pounds of 1000 cu. ft.	45.60	32.0	45.6	65.6	65.6
Heat-units in 1000 cubic feet	1,100,000	735,000	322,000	137,455	156,917

Gaseous Fuel

For use in steam plants, natural gas is about the only fuel of this nature considered, since artificial gas of any form requires the use of a producer and the cost of the producer and of attention is about as much as the same costs would be for a steam boiler, while the boiler would be needed in addition. Where natural gas is available at low cost, it makes an excellent boiler fuel. Natural gas as it comes from the well is a mixture of different gases, the greater part being usually marsh gas, oléfiant gas and nitrogen, the marsh gas being a hydrocarbon with 4 atoms of hydrogen to 1 of carbon (CH_4), and oléfiant gas having 4 atoms of hydrogen to 2 of carbon (C_2H_4).

The composition of different kinds of natural gas are given by Poole as shown in Table VI. As shown in the table the heat value of natural gas will run

from 800 to 1,100 B. t. u. per cubic foot and 1,000 cu. ft. of the gas will approximately equal 57.25 lb. of coal.

Producer gas and water gas are sometimes used as fuels, particularly for gas engine work, and the composition of such fuels is shown in Table V. This water gas is formed by blowing steam over heated fuel; the water is broken up into its constituents, hydrogen and oxygen, which unite with the carbon, forming hydro-carbon compounds and carbon monoxide. It has, therefore, much the same constituency as producer gas, except that less water goes into the fuel bed in the case of the producer.

Blast furnace gases are now used quite prominently, particularly in connection with gas engines. The blast furnace gas does not differ materially from ordinary producer gas. The composition of this gas is 3 per cent hydrogen, as indicated in the table. Before using it in a gas engine it must be carefully cleaned of dust particles; when used under a boiler this is not necessary.

TABLE VI.—HEAT VALUE AND PROPERTIES OF GASES AS GIVEN BY POOLE

Name or Location	Hydrogen.	Methane, CH_4.	Ethylene, C_2H_4.	Illuminants.	CO_2	CO	Oxygen.	Nitrogen.	H_2S	Calories per Cubic Meter.	B.T.U. per Cubic Foot.	Authority.
Anderson, Indiana.....	1.86	93.07	0.47		0.26	0.73	0.42	3.02	0.15	9494	1021	E. & M. Journal
Kokomo, "	1.42	94.16	0.30		0.27	0.55	0.30	2.80	0.18	9581	1030	"
Marion, "	1.20	93.57	0.15		0.20	0.60	0.55	3.42	0.20	9518	1024	"
Muncie, "	2.35	92.67	0.25		0.25	0.45	0.35	3.53	0.15	9477	1019	"
Louisville, Kentucky.....	1.31	87.75			6.60			4.34		8849	939	Slocum
Olean, New York.....		96.50		1.00		0.50	2.00			9900	1071	R. Young
W. Bloomfield, New York....		82.41		2.94	10.11		0.23	4.31		9158	998	H, Wurtz
Findlay, Ohio.....	2.18	92.60		0.31	0.26	0.50	0.34	3.61	0.20	10250	1100	E. McMillin
" "	1.64	93.35	0.35		0.25	0.41	0.39	3.41	0.20	9486	1020	E. & M. Journal
Fostoria, "	1.89	92.84	0.20		0.20	0.55	0.35	3.82	0.15	9450	1016	"
St. Mary's, "	1.94	93.85	0.20		0.23	0.44	0.35	2.96	0.21	9523	1028	"
Burn's well, St. Joe, Penna...	6.10	75.44	18.12	trace	0.34	trace				10090	1170	S. P. Sadtler
Cherry Tree, Penna.....	22.50	60.27	6.80		2.28		0.38	7.32		8034	840	"
Creighton, "		96.34		trace	3.64					9671	1025	F. C. Phillips
E Liberty, "	9.64	57.85	0.80	5.20		1.00	2.10	23.41		5581	592	S. A. Ford
Harvey well, "	13.50	80.11	5.72		0.66					9331	990	S. P. Sadtler
Leechburg, "	4.89	89.65	4.39	0.56	0.35	0.26				9962	1073	"
Grapeville (dry), Penna.....	7.05	35.08	0.17	28.87	0.58	0.22	0.16	27.87		7698	823	Morrell
" "	24.56	14.93	0.96	39.64	trace	trace	0.12	18.69		8326	891	"
Murraysville, Penna.....	19.56	78.24					2.20			8458	900	Rogers
Pittsburg, "	20.02	72.18		6.30	0.80	1.00	0.80			8620	917	Anon
Pechelbronn, Germany.....		77.03		4.8	3.6	3.5	1.8	8.9		8539	908	"
Caspian Sea, Russia.....		92.24		4.26	3.50					9859	1062	"
Aspharon Peninsula, Russia....	0.34	92.49		4.11	0.93			2.13		9859	1062	"
Blower in Mine, Wales.....		95.42			0.60			3.78		9578	1014	J. W. Thomas
Occluded gas, Wigan, Wales...		80.69	4.75		6.44			8.12		8770	930	"

Liquid Fuel

For power plant purposes this is practically crude petroleum, as none of the other forms of liquid fuel are sufficiently inexpensive to be practically usable. Fuel oil will weigh about 7.65 lb. to the gallon and the heat value per pound will run from 18,000 to 22,000 B. t. u. The composition of different oils and their heating value are shown in Table VII. The composition of the oil varies greatly with the locality from which it has been obtained and, of course, with the treatment to which it has been subjected.

As a rule, oil is not found available as fuel in the eastern part of the country, since the eastern oils are more valuable for other purposes than for boiler plants, and coal is at hand in large quantities. Through the southwestern part of the country, however, Texas and California oils are largely used.

It will be noted that most of the oils consist of carbon and hydrogen, although there is a small percentage of oxygen and occasionally sulphur, hydrogen and phosphorus are found, but always in such minute quantities as to be negligible for practical purposes.

In determining the value of oil as a fuel, the flash point and the specific gravity must be taken into consideration as well as the heat value. The flash point is that temperature at which inflammable gases will begin to come off from the oil so that a match or flame above the surface of the oil will tend to ignite these gases. The heavy oils, such as are used for power plant work, usually have a high flash point, since there is comparatively little volatile gas in them.

The specific gravity for heavy oils will usually run at 0.85 or heavier, and the flash point for such oils should be above 260 deg. F. The danger of explosion, of course, increases as the flash point is lowered, but is not great when the oils are properly stored. The light oils, i. e., those having a low specific gravity, are usually considered more valuable than the heavy ones, because they have more of the gasoline and benzine consistency and are, therefore, better for lighting and lubrication.

The specific gravity is not, however, an accurate measure of heat value of the oil. For such use as locomotives and steamboats, petroleum has the advantage of high heat value per pound and small bulk. The high cost has, however, prevented a large use in localities where coal was abundant and cheap. A certain advantage in cost of running the plant is obtained from the fact that there is no ash, no dust and no clinker. Care must be taken, however, that the fuel is thoroughly vaporized and that the furnace is suitable for the burning of oil as well as the burner being well designed to vaporize the oil.

Oils go by different names, depending on the treatment that they have received. The crude petroleum is that which comes from the well by direct pumping. Then we have different distillates which come off at different temperatures during the heating of the crude petroleum. Practically none of these are, however, available for power use, as the cost is too high. The

refuse from distillation or residuum oil usually has a flash point of 250 to 300 deg. and is suitable for use in any location as it is safe from any danger of explosion. Some of the advantages claimed for liquid fuel as given by Kent are:

"1. Diminished loss of heat up the funnel, owing to the clean condition the tubes can be kept in, and to the smaller amount of air which has to pass through the combustion-chamber for a given fuel consumption.

"2. A more equal distribution of heat in the combustion-chamber, as the doors do not have to be opened and consequently a higher efficiency is obtained.

"3. With oil there is no chance of getting dirty fires on a hard run, as with coal.

"4. A reduction in cost of handling fuel, since in one case it is all done mechanically or by gravitation,

TABLE VII.—COMPOSITION AND VALUES OF OILS

SOURCE	KIND	CARBON	HYDROGEN	OXYGEN	SP. GRAV.	FLASH POINT DEG. F.	B.T.U. PER HR.	AUTHORITY
PENNA.	LIGHT	82.0	14.8	3.2	.826	—	—	STIRLING
"	CRUDE	84.9	13.7	1.4	.938	—	20,736	URQUHART
WEST VA.	LIGHT	84.3	14.1	1.6	.841	—	—	POOLE
"	HEAVY	83.5	13.3	3.2	.873	—	—	"
"	CRUDE	86.6	12.9	0.5	—	—	21,240	POOLE
VIRGINIA	RESID.	87.1	11.7	1.2	.860	—	19,200	"
OHIO	CRUDE	80.2	17.1	2.7	.887	—	21,600	MAYER
TEXAS	"	85.7	11.0	3.31	.945	244	19,240	ORDE
WYOMING	—	—	—	—	.996	—	19,668	SLOSSON
CALIFORNIA	"	84.0	12.7	1.2	—	—	—	—
CANADA	"	84.3	13.4	2.3	.857	—	20,410	STIRLING
SHALE OIL	—	—	—	—	.875	288	18,217	LEWES
HEAVY TAR	—	—	—	—	1.084	218	16,050	LEWES
FRANCE	ST. GABIAN	86.1	12.7	1.2	—	—	—	—
ITALY	—	81.9	12.5	5.6	—	—	—	—
GERMANY	HANOVER	80.4	12.7	6.9	—	—	—	—
AUSTRIA GALICIA	CRUDE	85.3	12.6	2.1	.885	—	18,416	POOLE
ROUMANIA	—	82.6	12.5	4.9	—	—	—	—
CAUCASUS	HEAVY	86.6	12.3	1.1	—	—	20,136	URQUHART
"	LIGHT	86.3	13.6	0.1	—	—	22,027	"
"	CRUDE	84.9	14.0	1.25	—	—	18,610	ORDE
"	REFUSE	87.1	11.7	1.2	.886	350	19,832	URQUHART
RUSSIA	LIGHT	86.3	13.6	0.1	.884	—	22,628	POOLE
"	HEAVY	86.6	12.3	1.1	.956	308	19,440	STIRLING
BURMAH	CRUDE	86.4	12.1	1.5	.920	230	18,865	ORDE
BORNEO	"	87.8	10.8	1.24	.936	285	18,830	"
JAVA	"	87.1	12.0	0.9	.923	—	19,496	POOLE
BARBADOS	"	—	—	—	.958	210	17,718	LEWES

while with solid fuel a great deal of manual labor is required.

"5. No firing tools or grate-bars are used, consequently the furnace lining and brickwork floors, etc., suffer less damage.

"6. No dust nor ashes to cover or fill the tubes and diminish the heating surface, nor to be handled or carted away.

"7. Petroleum does not suffer while being stored, while the deterioration of coal under atmospheric influence is well known.

"8. Ease with which fire can be regulated, from a low to a most intense heat in a short time.

"9. Absence of sulphur or other impurities and longer life of plates, etc.

"10. Lessening of manual labor to fireman.

"11. Great increase of steaming capacity, as was conclusively proved when many factories returned to coal in Pennsylvania and Ohio; they had to increase their boiler capacity about 35 per cent."

An interesting comparison of results from the use of different fuels was reported to the Engineers' Club of Philadelphia in 1892, which showed that a pound of anthracite coal will evaporate 9.7 lb. of water from and at 212 deg. F., a pound of bituminous coal 10.14 lb. of water, a pound of fuel oil with specific gravity of 36 deg. Beaumé 16.48 lb. and a cubic foot of gas having a rating of 20 candlepower, 1.28 lb.

Calorimeter test of petroleum may be made by any of the methods given for coal in the article on this subject. While the use of petroleum fuel avoids ash, there is likelihood of the collection of tarry products on the tubes and in the flues, especially if care is not taken to secure smokeless combustion.

PEAT FUEL

An Assemblage of Facts From Various Authorities*

By Francis J. Bulask†

COMPARISON of peat with coal must be made at 2 points, efficiency and price. Unless there is a fair equality in the results of these factors, peat must be ruled out. If on the one hand it is so far below the level of coal in calorific value that no matter at what price produced it would not be used where coal could be had, or if on the other, it cannot be produced and sold for a price at least as low as that for which the equivalent in heating value of coal could be bought, all efforts to introduce peat will be unavailing.

Its Burning

Peat, when first placed on the fire, burns with a short blue flame, continuing to do so until the grate spaces become covered with embers, when it emits an intense yellow glow and short flame of the same color. It is now giving out an intense heat, which may be easily and accurately controlled by adjusting the draft. Once well lighted, a peat fire will not go out until every atom of fuel has been consumed.

Comparing the calorific value or heating effect of the various kinds of fuel, Thurston, in his Elements of Engineering, gives the following figures:

Fuel.	Calorific power. Relative.	Absolute B. T. U.	Water vaporized at boiling point. Parts by one part.
Coal, anthracite	1.020	14,833	14.98
Coal, bituminous	1.017	14,796	14.95
Coal, lignite, dry	0.700	10,150	10.35
Peat, kiln dried	0.700	10,150	10.25
Peat, air died	0.526	7,650	7.73
Wood, kiln dried	0.551	8,029	8.10
Wood, air dried	0.439	6,385	6.45

Furnace Requirements

The principal requirements for the satisfactory burning of peat fuel are: A thin fire; broad but short fire grate. The grate bars should be placed together about 3/8-in. apart, because the peat falling through the bars among the ash is wasted. The grate bars should be placed high up, near the flues and the fire box crown, because there is less flame in the peat than in coal. Not too much draft should be employed, because the peat is light.

A test of absolute heating power of peat was made by Professor Galloway of the Royal College of Science, Ireland, on 3 samples of dense peat for sale near Mountrath, Queens County, Ireland, with the following results:

Samples of dense peat tested for absolute heating power.	Absolute Heating Power by Thompsons Calorimeter. Lbs. of water at 212° F. converted into steam by 1 lb. of dense peat.	Lbs. of water at 212° F. converted into steam by 1 cu. ft. of dense peat.
Dense peat No. 1	6.05	240.87
Dense peat No. 2	5.50	343.75
Dense peat No. 3	6.33	464.07

*Authorities quoted:—
U. S. Bureau of Mines, Dept. of State, 1903.
Bureau of Mines, Canada, 1903.
U. S. Geological Survey, 1906.
Peat and Its Uses, by P. R. Bjorling and F. T. Gissing, 1907.
Chas. A. Davis, U. S. Govt. Peat Expert, 1908.
Bureau of Mines, Canada, E. Nystrom, 1908.

†Of the Peat Engineering Co., Toledo, O.

Tests on Peat

During a test of peat fuel as against coal at Horwich, in Lancashire under a steam boiler, the following results were arrived at. The test was carried out on 2 consecutive days, the fire having been raked out the night previous to the experiments. Coal got up steam to 10 lb. pressure in 2 hr. 25 min., and 25 lb. pressure in 3 hr. Peat fuel got up steam to 10 lb. in 1 hr. 10 min., and to 25 lb. in 1 hr. 32 min. 2,100 lb. of coal maintained steam at 30 lb. pressure for 9.75 hr., while 1,125 lb. of peat fuel maintained steam at the same pressure for 8 hr.

Canadian compressed peat fuel has been tested in locomotives with excellent results, showing that the thermal value of 100 lb. is equal to 95.13 lb. of coal. It was also tried at The Metropolitan Power House (Toronto Street Railway), and gave great satisfaction. The heat produced was much greater than that of coal, but it was somewhat deficient in lasting power. It has, however, the advantages that it gives no smoke, soot, dust or clinker, so that boilers will last much longer than if coal was used for generating steam.

Some years ago experiments were made on the Hartford & Springfield Railway, when a locomotive engine ran at express time a distance of 52 miles with 14,000 lb. of peat. It was found that ⅔ ton of peat was equal to 1 ton of coal for locomotive purposes. Later on, another experiment was made, an engine and 25 empty 8-wheel box cars starting from Syracuse with a little over 4 tons of peat. The steam was never below 120 lb. pressure, the train was 20 min. late on starting, which was made up in running 26 miles.

Use for Gas Producers

The chemical composition of peat does not differ greatly from that of wood and coal, viz., it is a mixture of highly complex chemical substances made up of definite proportions of carbon, a solid element and of hydrogen and oxygen, both gases at ordinary temperatures, combined in fixed quantities.

Gas has been made from peat successfully, both for illuminating, heating, and for Sir William Siemens' regenerative furnaces, and he stated that it was the best fuel for them. For this latter purpose this gas has always been used most extensively in Sweden for Siemens-Martin Steel, as well as for Glass houses.

FIG. 1.—TYPICAL PEAT FUEL FACTORY

TABLE I.—VARIATION OF PEAT VALUE WITH TREATMENT AND COMPARISON

CONDITIONS	MOISTURE %	ASH %	CARBON %	HYDROGEN %	NITROGEN % & OXYGEN %		B.T.U. PER POUND	AUTHORITY
AIR DRIED POOR	29.4	4.4	42.1	3.1	21.0		5,400	CLARK
" " GOOD	24.2	1.8	45.3	4.6	24.1		9,400	"
" " AVERAGE DRY.	0	4.0	59.0	6.0	1.25	30	10,040	STURTEVANT
CARBONIZED BY WET PROCESS AT 356 DEG. F. DRIED	0	3.0	61.9	6.8	1.2	27.1	10,500	EKENBERG
AS ABOVE FRESH PRESSED	50	—	—	—	—	—	4,870	"
AS ABOVE DRIED ONE WEEK	25	—	—	—	—	—	7,870	"
AS ABOVE BRIQUETTED	14.5	4.1	—	—	—	—	7,040	"
BRIQUETS CARBONIZED	4.1	3.7	—	—	—	—	10,350	"
PEAT COKE	—	5.6	84.4	2.6	7.4		13,425	"

SOURCE	FIXED CARBON	VOLATILE	MOISTURE	ASH	HYDROGEN	OXYGEN	NITROGEN	SULPHUR	B.T.U. PER LB.	AUTHORITY
FLORIDA-RAW BOG	2.58	4.68	92.41	0.33	—	—	—	0.05	—	U.S. GEOL. SURVEY.
BRICKS BEFORE DRYING	3.57	7.28	88.40	0.75	—	—	—	0.08	—	"
CAR SAMPLE	22.11	51.72	21.00	5.17	6.51	38.97	2.39	0.45	8,121	"
IRELAND	51.05	—	.10-25	2.55	6.85	39.55	—	—	—	KANE.
"	61.04	—	.10-25	1.83	6.87	30.46	—	—	—	"
FRANCE	57.79	—	—	3.33	6.11	30.37	—	—	—	REGNAULT.
PRUSSIA	50.13	—	15.17	8.20	4.20	31.14	—	—	—	—
"	55.01	—	21.7	21.17	5.96	35.24	—	—	—	—
GERMANY	56.48	—	17.63	9.86	5.92	38.35	—	—	—	JAECKEL
SWITZERLAND	40.10	—	23.17	7.87	4.53	21.51	2.84	—	—	JUPTNER

At Bofres Co.'s works, at Wermland, Sweden, there is an excellent peat gas producer in operation. It consists of an outside shell made of blast furnace slag bricks 12 in. thick, which is lined with fire bricks to a thickness of 6 in. This producer has 4 ash pits which are supplied with blast pipes, and a cast iron water bosh is provided, through which cold water circulates. It is charged through a cone shaped hopper, the cover being sealed with water when closed. The gas is led away to a condenser by means of a cast iron pipe, and on its downward course comes in immediate contact with a spray of water, and finally passes into a flue.

At Motala Steel Works, in Sweden, peat gas has been used for the last 30 yr., at first only for puddling furnaces, but subsequently for the open hearth furnaces. Two large producers are constantly employed. The gas is passed to the open hearth furnaces through a condenser to free it from some of its moisture. They have also a small peat gas producer in the rolling mills, and it has been found that the steel plates scale less when the furnaces are fired with peat gas. The peat gas at Motala is dearer than coal gas, but it is preferred before coal gas on account of the small amount of sulphur and phosphorus contained in it.

The peat employed in Sweden for the manufacture of peat gas has the following average composition: Carbon, 60.0 per cent; hydrogen, 6.4 per cent; Oxygen, 31.7 per cent; nitrogen, 1.9 per cent.

The gas has the following composition: Carbon dioxide, 6.9 per cent of volume; monoxide, 26.0 per cent of volume; hydrogen, 8.5 per cent of volume; nitrogen, 53.7 per cent of volume.

Electricity From Peat

Extract from test made at the peat gas power plant at Burangsberg, Sweden, where a gas engine of 60 effective horsepower is used for the operation of pumps and hoists in the mine in the vicinity. A brake test made early in 1904 gave the following results: Effective horsepower, 66.9; indicated horsepower, 82.3; consumption of fuel, 2.46 lb. per effective horsepower hour. The peat used contained, moisture, 39.71 per cent; ash, 4.38 per cent; combustible substance, 55.91 per cent; and had a calorific value of 4,840 B. t. u. per lb. The mechanical efficiency of the gas engine was 81.3 per cent, and the heat consumed per horsepower hour, 11,927 B. t. u. The producer was guaranteed to have 80 per cent efficiency, and the gas engine guaranteed not to consume more than 9,504 B. t. u. per horsepower hour with full load. Eighty per cent of 11,927 is equal to 9,515 B. t. u., which shows the guarantees were carried out.

Millions of acres of peat are now lying in this country, remote from coal mines and other fuel, at the same time in the midst of a rapidly growing population. This will soon make its presence felt. A recently developed 1 ton per hour portable self-contained peat fuel machine as designed by one of the leading peat engineering companies of this country which with one man will dig, treat and lay out to dry the equivalent of 1 ton of dry peat fuel an hour will, with a comparatively small outlay prove the splendid profits as well as fuel value to be had from peat.

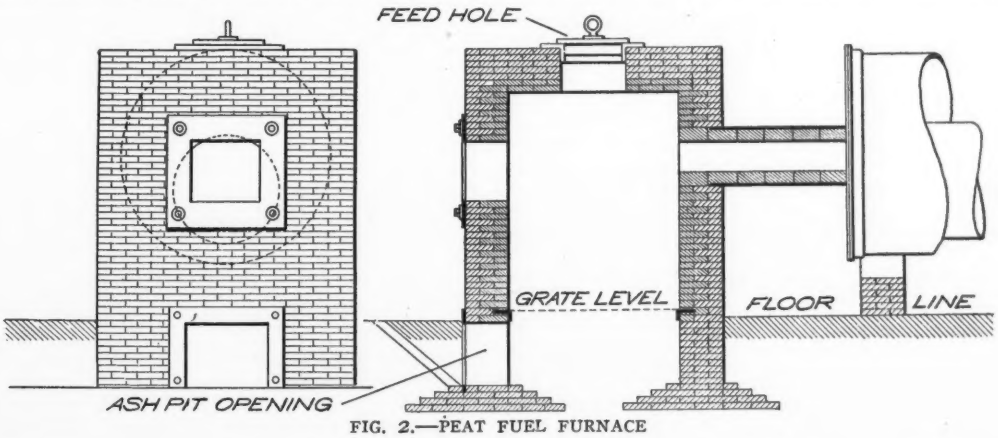


FIG. 2.—PEAT FUEL FURNACE

Referring to the illustration it will be seen that this automatic peat fuel machine consists of a 12 hp. gasoline engine, A, which drives an excavating and macerating machine, B, the purpose of which is to deliver a treated peat mass on to a steel slide from which it falls upon the ground in front of the field press. The machine is equipped with a pair of apron wheels, C, carrying the larger part of the weight of the machine and leading or steering wheels, D, which are connected by suitable gearing to the steering wheel, H.

A galvanized steel tank, E, contains water for cooling the engine, and a steel tank, F, is provided for holding the gasoline. The cooling water is passed

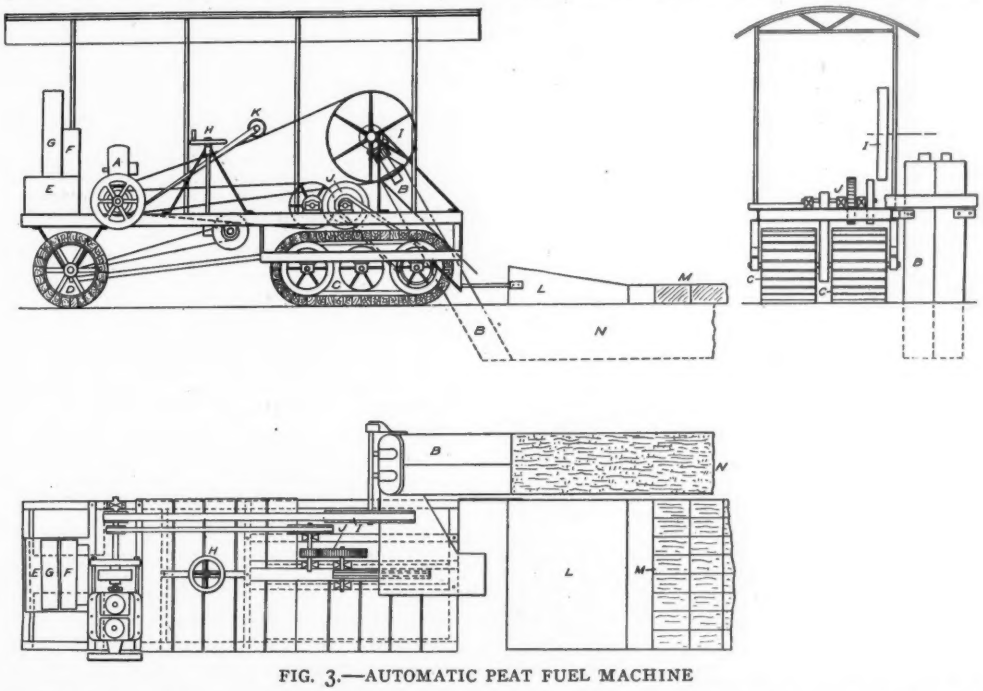


FIG. 3.—AUTOMATIC PEAT FUEL MACHINE

from the engine on its way to the storage tank through a radiator, G.

The excavating and macerating machine is driven by a belt pulley, I, the machine being driven by a train of gears, J, transmitting the power from the engine to the apron wheels. The steel peat spreader, L, levels the raw peat on the bog surface and cuts it into blocks of any size required. These blocks shown at M are spread out for drying. The ditch from which the peat is taken is shown at N.

M. Ekenburg, in a paper before the Iron and Steel Institute, gave some interesting data in regard to the treatment of peat by a new process. On microscopic and chemical analysis he has discovered that the difficulty with getting water out of peat is because of a cellulose coating around the peat particles which is broken up in heating the water at a temperature above 350 deg. F.

After the heating it is cooled and pressed to remove the moisture and the loss in this process is, about 14.3 per cent during the wet carbonizing process, 14.3 per cent for the heating, and 1.5 per cent as the fuel cost of running the press machines, making a total of 37 per cent of the fuel used up in the treatment process. The peat so made may be pressed into briquets without the use of any binder to stick the particles together, and these briquets are not injured by sudden heating and cooling and when burned give a flame more like a log fire than like coal. A pound of briquets gave about the same effective results as a pound of coal in trial firing on a locomotive.

Peat has also been treated for the formation of charcoal and coke for metallurgical processes, the resulting charcoal having about half the strength of wood charcoal and the coke, which was about 50 per cent by weight of the peat briquets used, having a crushing strength of 3,250 to 5,670 lb. per sq. in.

COALS

GRUNER'S CLASSIFICATION

DIVISION into classes may be made according to several different characteristics; the one most commonly used is Gruner's classification, which recognizes, first, anthracite or lean coals having a short flame, black color and specific gravity of 1.33 to 1.4 and which yield on coking 82 to 90 per cent of the weight of the coal reproduced in the coke and 12 to 18 per cent gas. This coal is found almost entirely in the Pennsylvania region, largely in the northeastern part, in the counties of Susquehanna, Lackawanna, Luzerne, Carbon, Schuylkill, Columbia, Sullivan, Northumberland and Dauphin.

ANTHRACITES		Eastern portion of Allegheny Mountains and Rocky Mountains in Colorado.
BITUMINOUS COALS.	Caking	Mississippi Valley.
	Non-caking	Maryland and Virginia.
	Cannel	Pennsylvania, Indiana, and Missouri.
LIGNITES		Colorado, Kentucky, and Washington.

The second classification is caking coals, which burn with short flame, are black in color and shining, have a specific gravity of 1.3 to 1.35 and yield from 75 to 80 per cent of fairly hard coke.

The third class is the furnace coals which burn with a longer flame than the caking, are black and shining and swell under the action of heat more than the others, have a specific gravity of 1.3 and yield from 65 to 75 per cent of fairly dense coke. These are specially adapted for coking and for forge fires.

The fourth class, long flaming coals, are dark in color and have a high luster, are hard and tough, with specific gravity of 1.28 and yield from 60 to 75 per cent of coke which is not hard. These are good for gas manufacture and for use in metallurgical work.

The fifth class, dry coals, burn with a long flame, are intense black in color and are hard, breaking with a shell-like fracture and having specific gravity of 1.25 and yield from 50 to 60 per cent of coke which is very brittle.

Market Classification

The common market classification of coals is, however, more nearly as shown in Table I, which is taken from Kent's book on Steam Boiler Economy. Kent's classification will be recognized as only a rough division, but serves pretty well to differentiate the various classes. The anthracite comes nearest to Gruner's lean coal and is more and more coming to be used only for domestic fuel, although in the smaller sizes through the east it is still largely employed for power purposes. The semi-anthracite is not a well-defined class of coal but corresponds to what might be termed a low grade anthracite. The semi-bituminous is quite a well defined class and corresponds quite well to the caking coals of Gruner's classification. The bituminous which includes the furnace coal and the long-flaming coal of the Gruner classification is the one most largely used for power plant work.

TABLE I.—KENT'S CLASSIFICATION OF COALS

	Fixed Carbon.	Volatile Matter.	Heating Value per lb. Combustible.	Relative Value of Combustible Semi-bit. = 100.
Anthracite	97 to 92.5	3 to 7.5	14,600 to 14,800	93
Semi-anthracite	92.5 to 87.5	7.5 to 12.5	14,700 to 15,000	94
Semi-bituminous	87.5 to 75	12.5 to 25	15,500 to 16,000	100
Bituminous, Eastern.	75 to 60	25 to 40	14,800 to 15,200	95
Western	65 to 50	35 to 50	13,500 to 14,800	90
Lignite	under 50	over 50	11,000 to 13,500	77

Lignite corresponds to the dry coal of Gruner and it will be seen from the various tables on properties of different coals that the rating of fixed carbon under 50 per cent and the volatile matter over 50 per cent is not warranted by the actual facts, although the heating value per pound of combustible and the properties as given by Gruner fairly well define the class.

In considering these coals they will be taken up in the inverse order of the classification, beginning with the poorest class and going upward to the anthracite. At one time it was considered that this was about the order of formation of the different coals from peat, that by process of pressure under water the peat was converted to lignite, the lignite to bituminous, then on to semi-bituminous, semi-anthracite and through to anthracite, the anthracite being the oldest form. The order of changes is not unlikely, but it seems from other observations that the lignite is simply a coal whose progress has been arrested and that in many cases the lignites are quite as old in the geological history as the other classes, but the development has not been carried so far.

Perhaps a better classification of fuels according to composition is that given by Butterfield, which rests upon the geological charge previously mentioned and shown in Table II. The variation here

is shown to be an increase of the total carbon and a decrease of the contained oxygen and hydrogen during the process of transformation from dry wood or vegetable matter onward toward anthracite. This corresponds also with the increase in heat value as we go from the wood upward to anthracite, because oxygen, as shown by David White in Bulletin 382 of the Geological Survey is really an impurity in coal and has the same effect as ash in reducing its heat value.

Here is one reason why the weathering of coals usually reduces their heat value, because they absorb oxygen from the atmosphere, this effect being particularly marked in lower grades such as lignites and sub-bituminous coals.

Lignites

As found in the mines, lignite varies from a brown to a deep black, according to its composition, the poorer grades carrying the earthy brown color and

TABLE II.—VARYING COMPOSITION OF COALS SHOWING GRADATION WITH FORMATION

	Carbon.	Hydrogen.	Oxygen.	Nitrogen.	Sulphur.	Ash.
Cellulose .	44·4	6·2	49·4	—	—	—
Dry wood (average)	48·5	6·0	43·5	0·5	—	1·5
Dry peat .	58·0	6·3	30·8	0·9	trace	4·0
Lignite .	67·0	5·1	19·5	1·1	1·0	6·3
Coal . .	77·0	5·0	7·0	1·5	1·5	8·0
Anthracite.	90·0	2·5	·25	0·5	0·5	4·0

the better grades the black approaching that of bituminous coals.

In the lower grades of lignite will be found some indications of the organic structure which is present in peat, while in the better varieties this indication is wanting. As the lignites are soft in texture and contain high percentages of hydrogen and oxygen they are more easily ignited than other coals and burn with a flame somewhat resembling peat.

Lignites absorb water easily and as seen from Table III, showing the composition of lignites, carry a high percentage of moisture which, of course, cuts down their heat value. The ash content will run from 9 to 58 per cent and with a lignite which is high in ash and also in moisture the heat value may be so low as to make it practically worthless for use in boiler furnaces. In such cases it has frequently been found available for use in gas producers, but, of course, to get the best results a large producer must be used. The lignites will not cake in the furnace, and, therefore, handle more nearly like anthracite than like bituminous coal, but because of the low heat value and the necessity for carrying a thick fire a much stronger draft must be provided than for anthracite.

As a rule the lignite coals are brittle and break up when they are thrown on the fire. They are also likely to break up when left exposed to the weather.

Bituminous Coals

Bituminous coals contain no bitumen whatever, the name having descended to us because of a misconception of their nature, due to the resinous feel of certain kinds. For the most part they are a dense black, but in some cases vary towards a brown. The luster is resinous, the coals that are the best quality are soft and silky to the feel.

Caking and the noncaking varieties have distinctly different characteristics. The noncaking coals are more like the lignites, rather hard and brittle and will not melt nor fuse together in the furnace or when coked. They burn with a yellow smoky flame and are good for use in gas making.

Caking coals when thrown in the furnace swell and fuse into a mass which must be broken up occasionally to allow the fire to get through it. These are, however, rich in volatile matter and burn with a long yellow smoky flame which makes it difficult to avoid making smoke when using them, particularly after green coal has been thrown on the fire.

Fields from which lignites and bituminous coals are drawn are quite well indicated by the localities shown in Tables III and IV. It is not, however, to be inferred that all coals from a given locality will have the same composition as those shown in the tables, since coals

TABLE III.—COMPOSITION AND PROPERTIES OF LIGNITES

LOCATION	FIXED CARBON	VOLATILE COMBUSTIBLE	MOISTURE	ASH	HYDROGEN	OXYGEN	NITROGEN	SULPHUR	B.T.U. PER LB.	AUTHORITY
KENTUCKY	40.00	23.00	30.00	7.00	—	—	—	—	—	BARR
ARKANSAS	34.50	28.50	32.00	5.00	—	—	—	—	—	"
TEXAS	45.00	39.50	11.00	4.50	—	—	—	0.66	13,100	UNIV. OF TEXAS
"	3.41	45.88	33.87	16.84	—	—	—	0.47	13,460	"
"	11.60	45.21	35.60	7.59	—	—	—	1.46	12,870	"
"	23.05	39.53	31.96	5.46	—	—	—	—	—	
NEW MEXICO	46.90	35.14	10.86	7.10	5.73	21.14	1.05	0.64	11,435	GEBHARDT
CALIFORNIA	49.70	—	—	13.80	5.78	30.19	—	1.53	—	SNOW
"	30.67	35.53	18.51	15.49	5.93	27.33	0.66	3.03	8,523	GEBHARDT
IOWA	35.60	37.03	8.45	18.86	—	—	—	—	8,720	KENT
OREGON	33.92	42.98	15.25	7.11	—	—	—	—	—	"
COLORADO										
GOLDEN CITY	34.89	44.74	17.15	3.22	5.14	14.60	1.50	0.42	9,778	POOLE
ERIE	45.98	32.71	18.57	2.74	4.25	6.85	1.64	0.52	11,360	"
GUNNISON	54.65	12.16	1.50	2.29	3.72	4.20	1.62	0.70	14,240	"
SO. PARK	58.62	33.79	6.30	1.28	5.23	18.86	2.35	0.47	12,204	"
UTAH	51.30	41.80	—	6.90	—	—	—	—	14,180	CARPENTER
WYOMING	36.37	40.49	6.38	8.82	—	—	—	0.99	13,440	SLOSSON
"	31.78	36.16	5.80	6.26	—	—	—	0.60	13,630	U.P. COAL CO.
"	45.98	32.71	18.57	2.74	4.25	6.85	1.64	0.52	—	BARR
WASHINGTON	58.25	31.75	7.00	3.00	4.55	17.25	—	1.00	—	
"	45.12	37.08	1.02	16.84	"	"	"	"	14,600	STATE OF WASH.
"	61.53	28.11	0.63	9.73	—	—	—	2.09	15,590	LABOR REPT
VANCOUVER	62.00	31.00	4.00	3.00	—	—	—	1.66	8,540	KENT
SCOTLAND	81.54	—	—	20.00	1.62	6.84	—	—	—	BARR
DEVENSHIRE	66.31	—	—	2.36	5.63	23.43 *	—	2.36	—	KENT
FRANCE	70.57	—	—	—	5.44	—	23.99	—	13,850	POOLE
GERMANY	28.33	47.83	25.92	2.92	3.75	15.83	—	—	10,962	BUNTE
AUSTRIA	71.78	—	—	—	4.93	—	23.29	—	11,950	SCHWACHOFER
BOHEMIA	79.34	—	—	—	4.41	—	15.65	—	13,401	"
HUNGARY	49.10	—	8.13	13.43	4.83	—	24.07	—	9,670	POOLE
BULGARIA	41.91	35.07	12.47	8.74	—	—	1.86	—	10,472	"
COLOGNE	63.29	—	—	8.49	4.98	—	26.54 *	—	—	KENT
RUSSIA	73.78	—	—	—	6.09	—	20.13 *	—	13,837	POOLE
STYRIA	57.78	—	—	7.86	5.34	—	35.98 *	0.90	—	KENT
AUSTRALIA					10.04	6.79	—	—	16,441	BARR
BLACK	83.17	—	—	—	4.71	12.35	—	0.69	—	SNOW
BROWN	73.80	—	—	8.00	—	—	—	—	—	

*WATER NOT INCLUDED

from the same mine in the upper and lower veins will frequently have widely different compositions. The only way to be certain as to what kind of a coal one is getting is by analysis, either proximate or ultimate, to determine the characteristics. As a rule, however, coal taken from the same vein of the same mine will show comparatively little variation and it is reasonably safe, if the mine and vein are known to assume a constant fuel value.

Since there is such wide variation in the composition of bituminous coals, in every case the furnace must be adapted to the particular coal to be used in order to get best results, which is not true in the case of the anthracites. This makes the design of furnaces for burning bituminous much more difficult and, in fact, it is impossible to design a furnace for general use with bituminous coals which will always prove satisfactory. The chief conditions which must be fulfilled in order to burn the volatile matter which always comes from bituminous coals and lignites are to have a large furnace and proper provision made for mixing the air and the gases, provision for keeping the mixture hot until ignition is complete, and ample grate surface or ample draft to burn the needed quantity of fuel.

These conditions are simple enough but to fulfill them in all cases is a problem which has taxed the ingenuity of the ablest engineers and, in fact, those who have had most experience agree that not only must the furnace be carefully designed to meet the necessities of the case, but that it must be carefully handled, as the successful burning of bituminous coal smokelessly and efficiently is quite as much a matter of careful attention to proper handling as of correct design of furnace.

TABLE IV.—PROPERTIES OF AMERICAN BITUMINOUS COALS

LOCATION	FIXED CARBON	VOLATILE	MOISTURE	ASH	HYDROGEN	OXYGEN	NITROGEN	SULPHUR	B.T.U. PER POUND	AUTHORITY
ALABAMA	48.30	42.76	3.01	5.93					14,017	BARR
CALIFORNIA	35.61	39.30	18.08	7.01					11,608	"
COLORADO	47.16	42.43	3.93	6.48					13,797	"
WALSEN RUN OF MINE	51.12	36.02	DRIED	12.86					12,130	STIRLING
GEORGIE	60.50	23.05	1.20	15.25					12,553	BARR
ILLINOIS MERCER CO.	54.80	31.20	8.40	5.60					13,063	"
" VERMILION CO.	45.37	43.70	5.78	5.15					13,746	"
" MT. OLIVE	37.10	35.65	11.00	13.00					10490	KENT
" STREATOR	40.70	33.30	12.00	14.00					10,580	"
" PANA SLACK	39.35	35.45	8.55	16.65				4.77	13,100	STIRLING
" LA SALLE	43.95	39.40	8.22	8.43					14,600	"
" DUQUION SLACK	41.60	35.95	6.05	16.40				5.14	14,370	"
" DANVILLE	45.37	49.70	4.78	6.15					14,050	"
" CARTERSVILLE-MINE RUN	52.17	34.11	4.87	8.85				0.85	14,150	"
INDIANA										
" BRAZIL	50.30	34.49	8.98	6.28				1.39	14,550	"
" BLOCK COAL	48.78	32.34	13.05	5.83					12,377	BARR
" CANNEL "	42.00	48.00	3.50	6.50					13,962	"
INDIAN TERRITORY										
CHOCTAW NATION	51.32	35.42	6.66	6.60					13,248	"
ATOKA	57.32	35.42	6.66	6.60				3.73	11,088	POOLE
C.O.&G.RY.CO. SLACK	56.29	27.91	2.78	12.20				0.92	12,256	ST. LOUIS SAMPL'G WKS
MC.ALEESTER	56.24	27.14	2.54	13.12				0.96	12,153	" " "
OSAGE C.&M.CO.										
KREBS LUMP	62.82	29.79	2.18	4.54				0.67	13,500	" " "
IOWA	45.88	40.21	5.16	8.75					13,247	BARR
" CENTERVILLE	46.64	37.77	5.52	10.07					12,460	STIRLING
" DES MOINES COAL-										
" CO., MARQUISVILLE	50.29	45.62	8.08	4.09					12,560	"
KANSAS, CHEROKEE	52.45	36.77	1.94	8.84					13,585	BARR
KENTUCKY	58.80	30.60	3.60	7.00					13,544	"
MARYLAND										"
" CUMBERLAND	73.57	15.47	1.23	9.79					13,205	"
" EUREKA				5.1					14 386	BARRUS
MISSISSIPPI	51.16	41.83	1.67	5.34	6.20	1.98			14,768	POOLE
MISSOURI										
PUTNAM CO.	46.24	37.48	9.03	7.25					12,852	BARR
HAMILTON	47.69	34.24	5.06	13.01					13,514	FORSYTH
MENDOTA	46.24	37.48	9.03	7.25					13,673	"
FRONTENAC (LUMP)	46.18	29.26	2.70	13.76				8.10	11,350	ST. LOUIS SAMPL'G WKS
GRADDY LEX.	42.19	29.01	9.24	15.18				4.38	10,849	"
PANAMA	48.68	30.91	4.49	11.74				4.23	12,307	"
MISSOURI	47.94	37.57	6.44	8.05					12,230	KENT
MONTANA	59.71	30.23	3.01	7.05					13,616	BARR
NEBRASKA										
ADAMS CO.	60.88	27.82	0.21	11.09					13,390	BARR
HASTINGS	60.88	27.82	0.21	11.09					14,583	FORSYTH
NEW MEXICO	51.50	35.00	3.10	10.40					13,208	BARR
NORTH CAROLINA	58.30	29.56	1.79	10.35					13,302	"
OHIO										
HOCKING VALLEY	53.15	35.88	6.25	2.72					13,591	BARR
UPPER FREEPORT										
SEAM, PA.& O.	51.63	37.35	1.93	9.10				2.89	14,750	STIRLING
JACKSON CO.	57.60	32.07	3.83	6.50					13,090	KENT
HOCKING VALLEY	48.85	34.97	6.59	8.00				1.59	12,130	"
SALINVILLE	50.95	35.00	3.15	10.90				1.86	14,730	STIRLING
MASSILLION	64.25	31.83	2.47	1.45				0.56	15,075	"
OREGON	45.17	37.83	8.00	9.00					12,754	BARR
PENNSYLVANIA										
PITTSBURG	54.94	35.34	1.80	7.92					13,762	BARR
CONNELSVILLE	63.26	28.71	1.93	6.10					13,881	"
YOUGHIOGHENY	58.40	35.00	1.00	5.60					14,208	"
PENNSYLVANIA	49 69	42.55	1.18	4.58				2.00	14,000	KENT
BUTLER CO.	48.97	39.88	1.91	7.22				1.97	14,200	STIRLING
BEAVER CO.	50.20	39.04	1.96	6.96				2.00	14,500	"
WASHINGTON CO.	50.99	37.11	1.16	8.72				2.06	14,700	"
BEAVER CREEK	55.42	34.33	1.50	8.75	4.89	6.90	1.40	1.96	14,762	LORD & HAAS
TENNESSEE, MARION CO.	54.81	31.94	9.16	10.09					13,185	BARR
SCOTT CO.	59.14	35.76	1.26	8.02				1.80	13,700	KENT
GLENMARY SCOTT CO.	61.63	31.47	2.15	4.75				0.94	13,167	"
ANDERSON CO.	58.41	34.86	1.29	5.44				0.20	13,050	STIRLING
FRANKLIN CO.	62.00	25.41	1.77	10.82				0.64	15,750	"
HARRIMAN	62.31	32.32		5.37				0.84	15,350	"
MORGAN CO.	61.66	34.55	1.67	2.14				0.88	15,150	"
TEXAS	43.54	40.20	6.67	9.59					12'906	BARR
CANNEL COAL, WEBB CO.	36.51	48.84	3.46	11.09				2.09	14,080	STIRLING
T.&P. COAL CO. ERATH CO.	43.15	33.20	5.83	17.82				1.51	15,000	"
VIRGINIA - COAL RIVER	58.89	35.89	3.35	1.25				0.62	14,950	"
" KANAWHA	60.67	34.08	2.10	2.50				0.65	15,150	"
W. VIRGINIA										
" " THACKER	56.03	35.04	1.38	6.27				1.28	14,040	KENT
" " CLOVER HILL	56.83	31.70	1.34	10.13	4.96	11.65			14,265	JOHNSON
" " MIDLOTHIAN	56.4	33.49	0.67	9.44	5.74	0.64			17,087	"
WYOMING, CHASE	44.75	34.50	14.50	6.25				1.03	13,156	SLOSSEN & COLBURN
" DEER CREEK	47.75	33.03	13.82	5.40				0.61	12,262	"
" GRINNELL	44.75	33.18	14.42	7.65				2.87	12,734	"
" SWEET WATER	55.70	36.95	5.55	1.80				0.86	14,348	"
ALMA NO.7 UPPER VEIN	48.75	34.88	7.37	9.00					13,330	"
" " LOWER "	51.75	33.55	8.82	5.90				0.65	12,824	"
ANTELOPE CAMBRIA	44.25	39.38	6.72	9.65				3.79	14,230	"
BECKER SHERIDAN	38.75	35.25	14.10	11.90				1.04	13,232	"
CASPAR NO.1	53.55	32.10	11.30	3.20				0.40	13,610	"

Semi-bituminous Coals

These are found from the eastern border of the Appalachian coal field across Pennsylvania, Virginia and Tennessee, a strip about 20 miles wide by 300 miles in length. They are among the finest of fuels for boiler furnaces, as they give a high heat value and with less difficulty in avoiding smoke than the bituminous coals proper. They are uniform in composition and in amount of combustible matter contained, as will be seen from the analyses given in the table. In appearance and in action they are more like the anthracites than the bituminous coals, but contain more of volatile matter than is found in the anthracites. The better classes, however, are almost free from smoke but are easier to kindle than are the anthracite coals. As the supply is limited these coals are not widely used for power purposes except in the eastern section.

The semi-bituminous and bituminous regions in Pennsylvania extend from the western side of the Susquehanna Valley, Lycoming, Huntington and Franklin sections to the western boundary, the semi-bituminous coming from the region along the eastern border of this strip and the bituminous from the western part of the state in the Pittsburg and Butler sections. In Maryland the Cumberland coal field, however, classes with the semi-bituminous varieties, the strip being some 30 miles long by 4 miles in width. Cumberland coal has always stood throughout the country for a standard of high quality and it is unfortunate, but true, that many coals have been sold under the name of Cumberland which never saw the Cumberland coal belt.

TABLE V.—PROPERTIES OF FOREIGN BITUMINOUS COALS

LOCATION	FIXED CARBON	VOLATILE	MOISTURE	ASH	HYDROGEN	OXYGEN	NITROGEN	SULPHUR	B.T.U. PER LB.	AUTHORITY
ALASKA										
" KOOTZNAHOO INLET	45.15	37.02	3.74	14.09	—	—	—	0.72	—	FOSTER
" COOK'S INLET	49.89	39.87	1.25	7.82	—	—	—	1.2		"
AFRICA, SONGWE RIVER, NYASSA	47.46	44.54	—	8.40	—	—	—	0.52	10,890	W. R. DUNSTAN
AUSTRALIA, LATHROBE VALLEY VICTORIA	40.18	34.66	22.08	3.45	5.01	24.00	1.30	0.17	11,415	JAMES STIRLING
AUSTRIA-HUNGARY										
DOMBRAU AUSTRIA	81.27		—	—	4.60	13.51	0.97	0.55	14,258	SCHWACKHOFER
PILSEN PRIESEN KAMOTAUER, AUS.	72.25		—	—	5.30	21.62	0.31	0.52	12,560	"
FUNFKIRCHEN HUNGARY	78.83		1.10	—	3.85	5.10	1.70	—	13,271	B. & H. ZEITUNG
SENGE SERVIA	46.88	36.15	13.32	4.05	3.78	20.73		—	13,113	WEITHOFER
" "	51.70	34.64	12.43	1.23	4.02	21.47		—	12,425	"
BRITISH COLUMBIA, VANCOUVER ISLAND	54.85	34.15	2.15	8.85	—			0.27		FOSTER
CHILI CERRO VERDE SO. BASIN	47.40	41.35	11.25	4.75	—	0.60	—	—	13,536	BOBINSKI
" SCHWAGER	57.85	40.40	1.75	14.00	—	0.70	—	—	14,204	"
" LOTTA	62.30	40.00	7.00	10.40	—	0.93	—	—	13,302	"
" PUNTA ARENAS	40.10	42.15	17.75	9.50	—	0.47	—	—	14,250	"
FRANCE										
DENAM	70.4	6.0	—	—	4.0		3.8		15,480	S. K.
BETHUNE	69.39	15.56	—	—	6.35		8.70		15,048	"
GERMANY										
HERMENEGILDE SILESA	81.61		—	—	4.79	13.17	0.20	0.23	14,461	SCHWACKHOFER
EWALD	83.10		—	—	5.38	10.86		0.66	14,323	BUNTE
LOUISENTHAL	58.78	30.20	6.97	4.05	4.42	2.43	—	—	13,509	"
TURN AND TAXIS, AVERAGE	57.85	29.89	6.59	5.67	4.93	9.90	—	—	13,682	"
GREAT BRITAIN										
DERBYSHIRE AVERAGE OF 8	56.30	41.00	—	2.65	4.94	10.28	1.41	1.01	14,616	ANON
LANCASHIRE " " 26	53.12	42.00	—	4.88	5.32	9.53	1.30	1.44	14,602	"
NEWCASTLE " " 18	57.23	39.00	—	3.77	5.31	5.69	1.35	1.24	15,203	"
WALES " " 37	68.09	27.00	—	4.91	4.79	4.15	0.98	1.43	15,123	"
WIGAN	64.10	28.31	4.64	2.75	4.96	8.46	1.44	1.24	14,679	"
NEWCASTLE	59.3	34.7	1.5	4.5				0.23		THWAITE
LIVERPOOL	54.9	39.96	.89	4.62	—	—	—	0.38		FOSTER
NEW CALEDONIA										"
NOUMEA	82.75	6.25	—	11.00	—	—	—	—	12,958	L. PELETAN
"	62.20	32.00	—	5.30	—	—	—	—	11,086	"
VOK	78.25	9.00	—	12.75	—	—	—	—	12,393	"
NOVA SCOTIA										
COOPERSTOWN	65.16	30.75	—	4.09	—	—	—	—	16,100	CARPENTER
CAPE BRETON			—	7.8	—	—	—	—	12,505	BARRUS
NOVA SCOTIA	63.61	32.38	—	4.11	—	—	—	—	16,000	CARPENTER
PICTOU	56.98	27.83	2.57	13.39	—	—	—	0.77	—	FOSTER
NEW ZEALAND										
MOKIHINUI WESTPORT	57.92	34.94	3.96	3.18	—	—	—	—	—	FOSTER
BITUMINOUS GREY RIVER WESTLAND	62.37	29.44	1.99	6.20	—	—	—	—	15,165	JOURNAL IRON & STEEL INST.
" ROSS SOUTHLAND	42.53	31.43	6.58	19.26	—	—	—	—	9,846	" " " "
BLACK COAL KAWA RIVER	50.15	42.63	4.18	3.04	—	—	—	—	12,215	" " " "
PITCH " GREY RIVER WESTLAND	60.20	29.97	8.01	1.81	—	—	—	—	15,075	" " " "
" " WHANGAREE	50.01	37.69	9.61	2.69	—	—	—	—	12,882	" " " "
ONTARIO										
SUDBURY ANTHRAXOLITE	—	0.52	4.00	1.52	—	1.69	1.04	0.31	14,654	W. H. ELLIS & LAWSON
RUSSIA										
KIRGHIS STEPPES	60.42		—	—	4.00	35.15	0.43	—	8,748	ALEXEJEW
NAGASSI SAGHALIEN	—	29.27	1.17	15.42	5.06	8.45	—	0.68	13,296	MIKLASCHEWSKI
BOGHEAD TULA	19.9	—	0.3	23.6	10.14	18.82	0.66	—	16,387	ALEXEJEW
JEGORSHINO URAL	92.34		1.3	3.1	3.45	3.05	1.16	—	14,381	"
HELAT CAUCASUS	60.4	—	—	—	4.77	17.92	1.80	—	12,816	"
SCOTLAND										
SCOTCH	48.81	39.19	3.01	9.94	—	—	—	0.36	—	FOSTER
BANNOCKBURN MAIN	68.10	27.40	1.75	2.75	5.14	5.67	—	1.89	15,523	ANDERSON & ROBERTS
KILSYTH COKING	67.82	28.45	1.72	2.01	5.20	7.53	—	2.04	14,603	" "
LOWER DUMGRAY AIRDRIA I	54.51	36.78	7.14	1.30	5.02	9.92	—	1.45	14,110	" "
" " " III	73.56	20.61	1.83	4.00	4.37	3.81	—	2.12	14,929	" "
VIRTUEWELL "	49.58	37.73	6.90	5.82	4.97	8.80	—	1.68	14,348	" "
SPAIN										
VERDENA LA PERMIA	58.16	41.84	—	4.40	—	—	—	—	9,556	R. ORIOL
SAMA	62.40	37.60	—	2.50	—	—	—	—	11,421	" "

Semi-Anthracite Coals

These approach closely to the anthracite coals in characteristics. They break with a conchoidal fracture and have a lustrous surface. They kindle with difficulty, are low in volatile and high in fixed carbon, but have more ash than the anthracites and somewhat more of oxygen. They are found only in a narrow strip along the western edge of the anthracite region

and when handled will soil the hands slightly. They are not, however, of great importance in the field of power plant work, as the supply is small and the cost is high.

A striking condition is found in Pennsylvania showing the transition from the bituminous to the anthracite coals. Kent states that in a distance of 50 miles northward from Bernice, in Sullivan county, to Gaines, in Tioga country, the coal changes from an anthracite having 8.9 per cent volatile matter and 91.9 per cent fixel carbon, to a distinct bituminous having 33.7 per cent volatile and 66.3 fixed carbon.

TABLE VI.—SEMI-BITUMINOUS AND SEMI-ANTHRACITE COALS. COMPOSITION AND VALUE

LOCATION	FIXED CARBON	VOLATILE	MOISTURE	ASH	HYDROGEN	OXYGEN	NITROGEN	SULPHUR	B.T.U. PER LB.	AUTHORITY
ARKANSAS FT. SMITH	73.05	17.2	1.07	8.68						FOSTER
MARYLAND CUMBERLAND	68.19	17.12		13.98				0.71		BARR
PITTSBURG, GEORGE'S CREEK	74.91	19.19	0.59	5.31				0.63	15,840	STIRLING
BAKERSTOWN "	72.93	17.17	0.60	8.76				0.59	15,840	"
LOWER KITTANNING "	76.58	16.92	0.74	5.86				0.68	15,840	"
MARYLAND	80.00			8.3	5.	2.7	1.1	1.2		
PENNSYLVANIA BLOSSBURG	73.11	15.27		10.77				0.85		BARR
BROAD TOP	77.30	15.61	0.79	5.40				0.90	14,820	KENT
CLEARFIELD CO.	71.82	22.52	0.76	3.99				0.91	14,950	"
CAMBRIA CO.	71.12	19.20	0.94	7.04				1.70	14,450	"
SOMMERSET CO.	71.51	16.42	1.58	8.62				1.87	14,200	"
BRADFORD	69.26	16.95	0.82	12.29				0.67	15,800	"
SULLIVAN	72.74	13.03	3.24	10.38				0.61	15,700	"
TIOGA	67.79	20.50	1.65	8.85				1.26	15,750	"
CENTRE	68.71	22.60	0.60	5.40				2.69	15,700	"
HUNTINGDON	76.14	17.38	0.78	4.81				0.88	15,800	"
CAMBRIA LOWER BED B.	68.94	21.21	0.74	7.51				1.98	15,750	"
" UPPER " C.	73.42	17.18	1.14	6.58				1.41	15,800	"
CLEARFIELD LOWER BED D.	74.08	21.10	0.81	3.36				0.42	15,800	"
" UPPER " C.	69.28	23.94	0.70	4.62				1.42	15,700	"
SOMMERSET	67.78	19.77	1.15	9.67				1.61	15,800	"
VIRGINIA										
POCAHONTAS	74.39	21.00	1.00	3.03				0.58	15,070	KENT
" RUN OF MINE	73.65	18.30	0.80	7.25				0.57	15,780	STIRLING
" " "	75.75	18.60	0.85	4.80				0.62	15,800	"
WEST VIRGINIA										
NEW RIVER	77.64	17.88	0.85	3.36				0.27	15,220	KENT
" " DIST. LUMP	79.26	18.65	0.76	1.11				0.23	15,820	STIRLING
" " " SLACK	79.40	17.57	0.83	1.92				0.28	15,830	"
LONGDALE	72.32	21.38	1.03	5.27				0.27	15,800	"
FIRE CREEK	75.02	22.34	0.61	1.47				0.56	15,800	"
ANSTED	63.10	32.61	1.40	2.15				0.74	15,350	"
WASHINGTON SKAGIT RIVER.	71.66	18.8	1.19	8.35						FOSTER
MEXICO	55.7	14.86	1.0	28.44				4.53		"
AUSTRALIA NEW SO. WALES	71.8	17.7	0.85	9.65				1.26		"
" MT. KEMBLA "	66.96	20.93	1.2	10.91				2.33		"
WALES	88.30			3.2	4.7	0.6	1.4	1.8		
MARYLAND GEORGES CR.	74.31	18.52	0.59	6.58					13,812	BARR
VIRGINIA CARBON HILL	71.00	18.60	0.40	10.00					15,800	STIRLING
W. VIRGINIA BARRS DEEP RUN	77.5	22.5							10,449	JOHNSON
" POCAHONTAS RUN OF MINE	73.65	18.30	0.80	7.25	4.13	2.65	0.85	0.57	15,682	LORD & HAAS
" " "	73.60	17.05	0.75	8.60				0.60	15,730	" " "
" " AVERAGE	74.52	18.10	0.73	6.65				0.60	15,739	" " "
" " LONGDALE	72.32	21.38	1.03	5.27				0.27	15,800	STIRLING
" " MINERAL CO.	72.99	19.39	0.76	6.86					13,764	BARR
FRANCE DOURGES	78.60	13.15			3.13	←	5.12	→	15,696	S.K.
" FOSSE DOUVRIN SLACK	72.25	14.30			3.83	←	9.62	→	15,408	"
" CREUZOT	79.49	10.58			4.10	←	5.83	→	16,560	S.K. & M.D
" RONCHAMP AVE. OF 5.	73.83	14.62			4.86	←	6.68	→	15,816	" " "
SPAIN ESPERANZA	77.2	22.7		4.89					12,663	R. ORIOL
" CATALINA	73.19	26.81		8.60					12,474	" "
" SANTA BARBRA	76.11	23.89		3.12					13,176	" "
" JUANON	79.1	20.9		4.90					12,942	" "

Anthracite Coals

Anthracites represent the highest quality of fuel known, the nearest to pure carbon combustible. They are found only in a few veins in Pennsylvania and in the Colorado Rockies and to a slight extent in Southwestern Virginia. Kindling is so difficult that for a number of years after the discovery of this kind of coal it was not used, being considered as too nearly like a rock to be burned. It was first used in 1766 for blacksmith work and shortly after came into considerable use for metallurgical processes, but even as late as 1812 it was unknown for any large use under boilers. At that time accidental success was attained in burning it and from that time on the use has been increasing, of late years by leaps, until the extinction of the anthracite supply is threatened within a few years.

Sizes of Coal

Bituminous and semi-bituminous coals usually crumble to powder when handled, particularly if left exposed to the open air for a time, as they absorb moisture rapidly and this moisture will not be driven off except by heating the coal up to 250 deg. F. Such coals are usually sold, therefore, as run-of-mine, which means that lumps and dust and all sizes between are sold in one mass.

Lignites break up less easily and can be graded but usually the price is so low that this is not worth while. The only coals, therefore, which are graded as to sizes are the semi-anthracites and anthracites, and for these the market sizes are as given in Table VII. The sizes used for power plant work are buckwheat, rice and slack, the slack being largely coal dust mixed with slate from the screenings. The size of coal very strongly affects the efficiency of the furnace.

W. L. Abbott, in some tests as to the effect of size

of coals, found that with a chain grate stoker the efficiency of the boiler increases with the size of coal up to a diameter of about ¼ in. then decreases until the diameter is about 0.45 in. and then again increases. fell off rapidly down to a size of 0.25 in. In all cases these coals were carefully screened to uniformity in size. Mr. Abbott explains this by saying that in the very fine coals a large percentage becomes ash; for in-

TABLE VIII.—COMPOSITION AND HEAT VALUE OF ANTHRACITES

LOCALITY	FIXED CARBON	VOLATILE	MOISTURE	ASH	HYDROGEN	OXYGEN	NITROGEN	SULPHUR	B.T.U. PER LB.	AUTHORITY
ANTHRACITE										
PENNSYLVANIA	78.6			14.8	2.50	1.7	0.8	0.4		SNOW
" BUCKWHEAT	81.32	3.84	3.88	10.96				0.67	12,200	"
" WILKESBARRE	76.94	6.42	1.34	15.3					11,801	CARPENTER
" SCRANTON	79.23	3.73	3.33	13.7					12,149	"
" "	84.46	5.37	0.97	9.2					12,294	"
" CROSS CREEK	89.19	1.96	3.62	5.23					13,723	"
" LEHIGH VALLEY	75.20	7.36	1.44	16.00					12,423	"
" LYKENS "	76.94	6.21							15,900	KENT
" " "	81.00	5.00							15,300	"
" WHARTON	86.40	3.08	3.71	6.22				0.58	15,000	"
" BUCK MT.	82.66	3.95	3.04	9.88				0.46	15,070	"
" BEAVER MEADOW	88.94	2.38	1.50	7.11				0.01		FOSTER
" LACKAWANNA	87.74	3.91	2.12	6.35				0.12		"
RHODE ISLAND	85.0			7.0	3.71	2.4	1.0	0.9		SNOW
WALES	91.7			1.5	3.78	1.3	1.0	0.7		SNOW
FRANCE	90.9			4.3	1.47	1.5	1.0	0.8		SNOW
" ANZIN FOSSE LAMBRECHT	86.2	6.0			4.0	←	3.8	→	15480	S.K.
FRANCE	94.00				3.17	6.83★			14,770	KENT
CHINA	96.83				2.16	4.99★			14,620	"
CREUSOT	89.56				3.78	3.83★			15,630	
SPAIN										
" TRANSPENA	91.90	8.10		3.64					13,413	R. ORIOL
" VALDECASTRO	92.95	7.05		3.60					13,969	" "
ARKANSAS	74.49	14.73	1.52	9.26					13,217	BARR
SEMI-ANTHRACITE										
FRANCE BASCOUP	84.42	7.66			6.04		1.88		15,480	S.K.
" MONCEAU FONTAINE	82.71	0.57			3.98		12.74		15,300	"
" DOUVRIN	86.48	1.07			3.77		8.68		15,012	S.K. & M.D
" FOSSE DOUVRIN LENS	87.34	3.84			3.96		4.86		15,552	S.K.
GERMANY ALTENDROF	83.87	6.05			4.18	3.90	1.00	1.00	15,975	"
SPAIN PREVENIDA	82.8	17.2		4.28					13,230	R. ORIOL
" CONVENIENCIA	83.7	16.3		3.95					13,050	"
PENNSYLVANIA LOYALSOCK	83.34	8.10	1.30	6.23				1.03	15,400	KENT
" BERNICE	82.52	3.56	0.96	3.27				0.24	15,050	"
" "	89.39	8.56	0.97	9.34				1.04	15,475	"
" WILKESBARRE	88.90	7.68		3.49					14,199	BARR
" LYCOMING CREEK	71.53	13.84	0.67	13.96				0.03		FOSTER
VIRGINIA NATURAL COKE	75.08	12.44	1.12	11.38				0.47		"
ARKANSAS	74.06	14.93	1.35	9.66						U.S. GEOL. SURVEY
INDIAN TERR.	73.21	13.65	5.11	8.03	4.65	6.17	1.60	1.18	13,662	" " "
WALES CARDIFF	81.9	12.85	1.25	4.				0.76		FOSTER
MARYLAND EASBY	83.6	16.4							11,207	JOHNSON

★ HYDROGEN, OXYGEN, NITROGEN & SULPHUR

He explains this by saying that "Performance becomes better until the point is reached when the quantity of large pieces becomes so great that there is not enough fine material to close up the holes; the efficiency drops off until, owing to greater agreement in size, the particles begin again to fit together and produce a homogeneous mass."

For coal screened to size it was found that the efficiency increased as the size of coal decreased from a diameter of 1.25 in. down to diameter of 0.75 in. and then stance, in the coal 1.25 in. diameter the ash was 13.7 per cent, while in the coal 0.25 in. in diameter the ash was 30.8 per cent, and a different series of tests made in the same plant showed that with coal of 40 per cent ash burned on a chain grate stoker, the efficiency drops to zero because not enough coal can be burned to generate any power in the boiler. It is, therefore, evident that too large a percentage of dust in coal is productive of great decrease in its value as a power-making fuel.

TABLE VII.—CLASSIFICATION OF COAL BY SIZES

Trade Name.	Size of Screen. Over.	Through.
Run of mine	All sizes mixed	
Lump	5 inches	
Furnace lump	Selected for blast-furnace	
Steamboat lump	4½ inches	7 inches
Broken or grate	2½ "	4½ "
Egg	2¼ "	2½ "
Large stove or stove No. 1	1½ "	2¼ "
Small stove, stove No. 2, or range	1¼ "	1½ "
Chestnut	¾ "	1¼ "
Pea or nut	⅝ "	¾ "
Buckwheat, or buckwheat No. 1	⅜ "	⅝ "
Rice, or buckwheat No. 2	⅛ "	⅜ "
Barley, or birdseye	⅛ "	⅛ "
Culm	Dust	

TABLE IX.—RELATION OF SIZE OF COAL TO EVAPORATIVE VALUE

Kind of Coal.	Pounds of Water per Pound of Coal from and at 212°.	Pounds of Water per Pound of Combustible from and at 212°.
Buckwheat	8.77	11.07
Rice (No. 2 buckwheat)	9.05	11.18
Culm (pea, buckwheat, rice, barley, dust)	8.74	11.19
Barley (No. 3 buckwheat)	8.39	10.89

NEXT TO THE RAW MATERIAL itself, mechanical power is the basis upon which all industry rests, and what can be more significant of improved conditions than the additions now being made to power generating and driving machinery?

BRIQUETS

NUMEROUS experiments have been made with this class of fuel at various times, some of the results of different experiments being shown in Fig. 1. No logical reason has been advanced, so far as the furnace is concerned, for some of the peculiar shapes adopted, but the matter of formation of the briquets in presses in some instances governs the shape adopted.

One firm which has had a large experience in the making of briquetting machinery and installing plants states that this class of fuel at the present time, on account of the cost of manufacture, is not an available source for power plant fuel, that it is suited at present prices only for domestic use. Other experimenters who are enthusiasts on the subject claim that with slack coal and culm, which is almost if not quite worthless, the briquetting adds enough to the efficiency of the fuel to pay for the process, even for use in power plants. The cost of briquetting, including all fixed charges, is given at from $1 to $1.50 a ton, outside the cost of the coal dust. It will be shown in the section on furnaces that even the poorest grades of slack can be burned with quite good efficiency in the natural state, so that it is doubtful whether the cost of briquetting for power plant use is a good engineering investment.

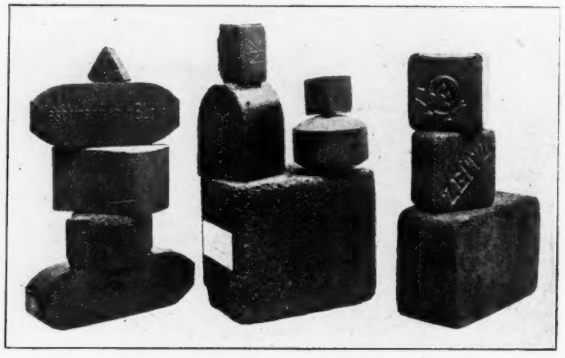
Two classes of briquetting machines have been developed, one making a small briquet comparable with the larger sizes of anthracite coal, the other making a large briquet the size of a paving brick, which must be broken up before it is available for use in boiler furnaces.

A plant installed near Belfast, Ireland, by an English manufacturer uses clean slack coal with a mixture of 5 to 10 per cent of pitch, ground and heated in a pug mill and then pressed into bricks 5 by 5 by 3 in. These bricks, it is claimed, will burn in an ordinary house furnace or stove much like a chunk of wood and if broken up give a hot fire like small coal.

The most extensive series of tests on the matter of briquetting and the use of briquets is that carried out by the United States Geological Survey in the testing plants at St. Louis and at Norfolk, Va. The Norfolk tests, being the latest, have greater value and were undertaken to determine the per cent pitch or other binder needed for satisfactory briquets, what kind of binder was best and the comparative value of briquets and run-of-mine coal as fuel. The English machine used at Norfolk made rectangular briquets 6.75 by 4.25 by 2.5 in., weighing about 3.75 lb. each, and turned out about 3.8 tons an hour. The American machine made cylindrical briquets with convex ends 3.25 by 1.5 in., weighing 11 oz. each and had a capacity of 8.9 tons an hour. Both machines were of the plunger type, forcing the material into molds, the English machine having a plunger which forced into molds on a vertical revolving table, while the American machine, which was made by the Renfrow Co., forced the material from both ends of the plunger into molds from which they were thrown out onto conveyor belts.

Two kinds of binders were tested, water gas pitch of various sorts and flour. Comparative tests indicated that the briquets made with the flour binder are stronger under crushing tests but do not stand weathering as well as those made with pitch. The tests at St. Louis as well as at Norfolk showed that satisfactory briquets can be made from almost any coal and that in many cases where the cost of the fuel is very low, the value can be raised sufficiently by briquetting to more than pay for the cost of the work. This is, however, largely because the fuel is then made suitable for domestic use, which is not the case when it is in the form of dust.

In burning the briquets it was found much easier to fire without smoke than when burning the coal before briquetting, and the tests with locomotives have borne out this conclusion. The weathering tests showed that the quality of the briquets varies considerably, both with the kind of coal used and with the amount of binder. So far as making the briquets is concerned, about 6 to 10 per cent of binder is found sufficient, but the weathering showed that those having only a small percentage of binder are more quickly disintegrated by the weather. In some cases the



VARIOUS FORMS OF BRIQUETS USED

entire pile of briquets was broken down by the weathering and had lost their original shape.

As a rule the briquets containing 7 to 8 per cent binder were satisfactory and the treatment raised the heat value of the fuel materially. The effect of briquetting on efficiency of fuel is shown in some locomotive tests in which it was proved that used on the Atlantic Coast Line Railroad run-of-mine coal required 15.8 lb. of coal per car mile as against 12.5 of briquets. The briquets also gave a hotter fire, so that the trains made faster time and the matter of smoke was practically eliminated.

Other tests made on railroads running out of Chicago gave an efficiency of 59 per cent when using a coal from Oklahoma and 66 per cent when using briquets made from this coal.

As an idea of the extent of the industry, in 1907 there were 10 coal briquetting plants in the United States having a total production of 63,000 tons a year. The cost of manufacture, including the binder, wages and power used, is about 40c a ton, which does not include the overhead charges or cost of superintendence. The cost of binder is from 20 to 90 cents a ton, according to the material used. It is found that if ordinary hard pitch is used the briquets are brittle and break easily, while if the pitch used is too soft there is difficulty from smoke. Handling of the briquets has been found to give on the average about 8 per cent reduced to dust.

At Stockton, Cal., some experiments have been made in briquetting lignite and the screenings of bituminous coal. The residue from California oil was used as a binder, the briquets being put up to weigh from 6 to 9 oz. each. Tests on the Missouri Pacific Railroad with briquets from Arkansas semi-anthracite as compared with Illinois lump coal showed an increased evaporation of 23 per cent and a reduction in

fuel consumption of 3.7 per cent in favor of briquets. A table showing the results of some tests and the composition of fuels is given herewith, the table being taken from Engineering News of August 5, 1909.

More has been done in regard to the testing and use of briquets in locomotives than in stationary plants, partly because the problem of carrying and handling fuel in the locomotives is a more difficult one, partly because getting rid of smoke which is made by the locomotives is a harder problem than for stationary boilers.

Peculiar conditions are sometimes encountered. Briquets made from the Arkansas coal weighing 4 lb. had to be broken up before firing in order to hold the fire in good shape, while similar briquets made from Illinois coals were fired whole with good results.

The results obtained by Mr. Abbott, showing the greater efficiency of coal of uniform size over run-of-mine, account in part for the better results obtained with briquets. The briquets also made less clinker and ash than the mine run.

In the government tests, the heavy tar remaining from petroleum distillation was found the best binder, while the water gas tar pitch was found second in value. Experiments are now being carried on at Pittsburg by the Fuel Testing Plant in regard to briquetting, lignite having been given considerable attention, but final results have not yet been obtained.

Briquetting of peat is one of the most satisfactory methods of using that material, one method being to press the peat into briquets and then form it into coke. Usually for this process the peat is sufficiently moist so that no binder is required which considerably reduces the expense, as the cost of pitch for binder is from $10 to $12 a ton.

As to the machinery used for briquetting, 2 styles of presses have been developed, one having plungers which force the mixed slack and binder into molds, the other catching the material between 2 wheels in the rims of which pockets are formed, thus squeezing the material into oval lumps about the shape and size of a cake of toilet soap. The plunger press type is represented by the machines of the Henry S. Mould Co. of Pittsburg, and the roller press type by the machines made by Chisholm, Boyd & White of Chicago.

In European countries the use of briquets is much more common than in the United States and it is estimated that some 40 per cent of all the coal used on the railways is in the form of briquets.

W. H. Booth gives the cost of labor and fuel for making a ton of briquets as from 30 to 50 cents a ton. Besides this there is the cost of the pitch and of the coal dust which may run from 70 cents down to 40 cents a ton. Of course, the labor cost depends upon the locality where the briquets are manufactured, but these figures would make the total cost of briquets for labor and binder vary between $1 a ton and 70 cents.

Tests just reported of run-of-mine coal as compared with briquets made from the same coal on the torpedo boat "Biddle," which has Normand water-tube boilers with low and small furnace, showed no advantage from the standpoint of efficiency in briquetting, in fact some of the larger briquets showed lower efficiency than the coal. These briquets were made up with a binder of water gas pitch in amount equal to 6 per cent of the coal. With the New River run-of-mine coal it caked badly and had to be broken up after nearly every firing.

The briquets, on the other hand, burned freely with no crumbling. With this kind of a furnace it was not found that briquetting was of any assistance in avoiding the production of smoke. The table herewith gives a comparison of the coal before and after briquetting, as to the constituents.

These briquets were of the sizes given in column 1 on page 30, made by the 2 briquetting machines in the government testing plant.

Tests have also been made along the same lines using run-of-mine and briquetted coal in locomotives. In this instance the trials were made on the Seaboard Air Line Railway, the fuel used being coal from the Turkey Gap mine in the Pocahontas No. 3 bed, West Virginia. The briquets were practically the same in size and proportion of binder as those used in the marine tests.

The locomotive firebox was 108 in. long, 55 in. high and from 41 to 55 in. wide, equipped with rocking finger type grates, and the boiler had a ratio of heating to grate surface of 87.2 to 1 and 30 per cent air space through the grates. A firebrick arch was used to throw the volatile gases to the top of the firebox before allowing them to pass through the tubes.

Six tests were made on run-of-mine coal, 4 on large and 4 on small briquets, the rates of combustion running from 18 lb. to 110 lb. of dry fuel per square foot of grate per hour. The following conclusions were reached: For the locomotive used, at low rates of working run-of-mine gives somewhat higher evaporation per pound of fuel than briquets; at medium rates there is little difference, and at high rates of working the briquets are considerably better. The small briquets are easier to fire than large ones and either form is better than run-of-mine. The briquets produced about as much smoke as the coal under similar conditions, part of this blame resting, however, on the pitch binder.

Suggestion was made that it might pay to add combustion chambers several feet long to the front ends of locomotive fireboxes, using a large number of boiler tubes of smaller diameter and shorter. The firebrick arch used in this locomotive was found to be of material help in securing good combustion.

TABLE SHOWING RESULTS OF COMPARATIVE TESTS OF COAL AND COAL BRIQUETTES FOR LOCOMOTIVE FUEL.

Railway	Chicago, Bur. & Quincy				C., R. I. & P.		Missouri Pacific			Chicago & E. Ill.		Chicago B. & Q.	
Coal for test	Carterville District, Illinois				Harishorne, Okla		Pittsburg, Kan.			Sullivan Co., Ind.		Bevier, Mo.	
Fuel tested	Briquettes Washed	Briquettes Unwashed	Coal 3-in. lump	Coal Mine run.	Briquettes Unwashed	Coal Lump	Briquettes Washed	Briquettes Unwashed	Coal Lump.	Briquettes	Mine run coal	Briquettes	¾-in. lump coal
Proximate analyses; fuel as fired	....	....	....	....	....	....	....	....	....	....	....	....	....
Moisture	5.67	5.41	5.59	4.70	2.1	2.54	3.44	2.49	5.47	7.14	13.86	7.69	11.40
Vol. combustible	31.00	31.86	32.67	35.04	35.65	36.08	33.21	31.15	29.15	36.02	32.13	32.86	33.55
Fixed carbon	30.75	51.38	52.80	47.14	50.74	53.97	52.45	47.33	49.81	44.18	41.90	39.52	42.12
Ash	12.49	11.35	8.94	13.12	11.51	6.51	10.90	19.03	15.57	12.66	12.06	19.93	13.93
Sulphur	1.11	1.87	....	....	1.63	1.75	3.67	4.43	4.80	3.63	3.48	4.50	5.78
B. T. U. per lb. fuel as fired	11,969	12,163	....	....	13,015	13,681	13,033	11,713	11,422	11,711	10,553	10,429	10,556
Fuel consumed per sq. ft. of grate surface per hour, actual	73.7	73.2	80.9	85.7	44.3	55.2	75.0	78.2	92.1	48.0	53.0	71.0	63.0
Water evap. per lb. of fuel	8.66	8.36	8.99	8.15	9.00	8.34	8.94	8.89	7.13	7.25	6.77	7.00	6.81
Water evap. per lb. of dry fuel	9.09	8.86	9.52	8.56	9.20	8.56	9.15	9.12	7.64	7.79	7.56	7.53	7.01
Equivalent evap. per sq. ft. of heat. surface per hour	9.97	9.94	11.60	11.20	6.96	8.02	9.49	9.97	9.42	6.56	6.90	6.78	6.76
Boiler HP. developed	792	780	912	873	522	599	813	854	809	469	485	604	604
Boiler efficiency	69.5	66.5	....	....	66.8	58.7	65.5	75.8	60.2	59.6	62.4	64.8	64.2

	FIXED CARBON	VOLATILE MATTER %	ASH %	STORAGE VALUE %
JAMESTOWN NO. 6 — MINE RUN AVERAGE.	75.35	19.18	5.48	100.
LARGE BRIQUETS ... " ...	72.42	22.61	4.97	73.0
JAMESTOWN NO. 11 — MINE RUN AVERAGE.	77.41	16.29	6.30	
SMALL BRIQUETS ... " ...	76.11	17.91	5.98	77.4

ESTIMATING COAL VALUES

CORRECT SAMPLING AND DETERMINING QUALITY

IT IS becoming generally recognized that the value of a coal does not depend upon its weight, but upon the heat units which it will give up to the furnace when burned. Evidently ash is an adulterant, for what we want out of the fuel is combustible. Also the value depends upon the moisture contained, since all moisture in the coal must be evaporated by heat from the coal. The amount of heat per pound of coal as determined from its constituents has already been discussed under the subject of Combustion, so that what remains is to determine what are the constituents in any given sample of coal.

The method of testing is fairly well outlined by the United States government which now purchases most of its fuel supply on specifications which base the payment on the number of heat units contained in the coal and the amount of ash. The reason for this is that when we buy coal what we are really buying is heat units, and while the price is supposed to be based upon the heat value, unless some method is employed of keeping track of the heat value in the coal we may be buying slate or water, neither of which will be helpful in trying to get heat units out of the fuel. It is reasonable to put a penalty on too large an amount of ash, not only because we have to buy more tons of coal to get the same number of heat units, but because the handling of a greater amount of ash from the ashpit involves more work and it requires a larger grate to burn fuel enough to give the desired power and it requires more labor in handling the coal to shovel a million B. t. u. under the boiler than if no ash were present.

In sampling coal the great difficulty is to get a truly representative sample. In many coals large chunks of slate are contained and in taking even as large a sample of coal as 100 lb., if there are 1 or 2 lumps of slate it will increase the ash content very materially. It is wiser, therefore, to take samples from a large number of places in the coal supply with a considerable amount from each carload, or, if it is being handled by a conveying system, a good many small samples from different parts, so that the pile with which the sampling is commenced will be some 300 or even 400 lb.

This pile should then be shoveled over until thoroughly mixed, the large chunks broken up as mixed, so that there will be no pieces over a couple of inches in diameter in the pile. After this thorough mixing the pile should be quartered, i. e., divided by 2 lines at right angles to each other, as nearly as possible into 4 equal parts. Two diagonally opposite piles are then thrown away and the remaining 2 piles again thoroughly mixed and broken down still finer. Pieces in this instance should be not over 0.5 in. in diameter. After a thorough mixing a second quartering is made, the 2 diagonally opposite piles thrown away and the other 2 piles again mixed, and so, pulverizing, mixing and quartering, the sampling is brought down to an amount that can be put into 3 or 4 glass jars. This remainder is then put into the jars which are sealed and carried to a laboratory for analysis.

For the proximate analysis a sample of about 100 lb. is usually quartered, and a quarter of this or sometimes half of it used for the proximate determination of moisture. This sample is placed in a shallow pan not over 3 in. deep, carefully weighed and the pan then put in the hottest place that can be found, usually on top of the boiler setting or flues, kept there for at least 12 hours, preferably 24, and then weighed again to determine the loss in weight by driving off moisture. This determination is compared with the laboratory determination made on the sealed samples.

Proximate Analysis

Proximate analysis does not give us the exact constituents of the coal but it enables us to judge about what a coal will do. Two coals which show the same fixed carbon, volatile matter, ash and moisture will give reasonably near the same number of heat units per pound and by comparing the proximate analysis of any coal which may be tested with those given in the fuel tables in this issue, the probable heat value can be determined closely enough for practical purposes.

The proximate laboratory determination, which is the one to be used for coals mined west of Pittsburg, or for other coals which have a large amount of moisture, is to take one of the samples in the glass jar after bringing it to the laboratory, weigh the coal carefully, then spread it in a thin layer and expose it for 10 or 12 hours to the atmosphere of a warm room, weighing it afterwards to determine the amount of surface moisture contained, then crush it all in a coffee mill to grains somewhat less than 1/16 in. in diameter, mix this sample thoroughly and select a portion of about 28 grams to weigh in a balance, which should be accurate enough to show a variation of one part in a thousand.

Dry this in an air or sand bath at about 240 and 280 deg. F. for 1 hr., weigh it and record the loss. A sand bath consists of an iron dish filled with sand and in this sand rests the platinum dish containing the coal to be dried out. The iron dish or vessel should either be closed in the form of an oven or should have sides high enough so that none of the moisture from the flame can by any possibility get to the coal. There must, of course, be an opening at the top of the iron vessel to allow the escape of moisture which evaporates from the coal.

Heat and weigh again at intervals of an hour or less, repeating the process until the minimum weight has been reached and the weight begins to increase by oxidation of the coal. The difference between the original and minimum weights is taken as the moisture in the air-died coal.

This test should preferably be made in duplicate and the results of the 2 tests ought to agree within less than ½ of 1 per cent, the mean of the 2 determinations being taken as the correct result.

For the rest of the proximate analysis the sample of coal already dried out is put into a platinum crucible and covered with a lid and gradually raised in temperature to a red heat, at which it is maintained for a few minutes until gas ceases to be driven off. The crucible and contents are then cooled in a desiccator, which is a glass jar containing some chemical substance such as sulphuric acid or calcium chloride to absorb all moisture, and the crucible is weighed.

The loss in weight due to this red heat is recorded as the volatile matter. The crucible is then raised to a white heat with the lid partly open so as to admit air to burn the coal, and the heat is continued until all carbon is burned away, leaving nothing but ash. This, after cooling, is weighed again and the difference between this and previous weights is recorded as fixed carbon; the remainder, of course, is ash.

The determination of moisture and ash by this process is practically accurate but it is evident that there may be a slight error in regard to the proportions between volatile matter and fixed carbon. Such a proximate analysis should be repeated on several samples.

Ultimate analysis of coal for its absolute chemical constituents is a delicate process and one difficult to be carried out. It should be attempted only by those who are skilled in making chemical analyses and any description is, therefore, out of place in this issue.

CALORIMETRY

TESTING HEAT VALUES OF FUELS

FOR DETERMINING the real heat value of a fuel, the calorimeter test is better than the determination of the ultimate composition and calculation by formula. This calorimeter test may be conducted with any one of a number of different kinds of apparatus. The most accurate device so far brought forward is the Mahler bomb calorimeter. It has its drawbacks, since in order to use it a tank of pure oxygen gas under high pressure must be available but it has the advantage of being accurate and with it tests can be repeated and results checked very closely.

The Mahler Bomb

This apparatus consists of a steel shell B with cover, capable of withstanding a pressure of 50 atmospheres. The capacity is about 40 cu. in. and the weight 9 lb. The walls are 0.3 in. thick. On the interior it is lined with a coating of enamel to resist corrosion and

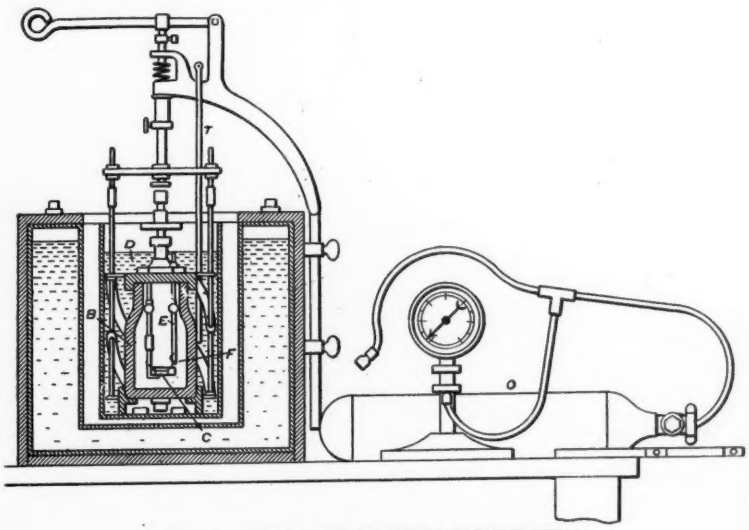


FIG. 1.—THE MAHLER BOMB CALORIMETER

nickel plated on the outside. In the cap is a tube with stop cock, through which runs a well insulated electrode with a platinum wire on the inner end. The second platinum wire of the circuit supports a small disk on which the fuel to be burned is placed.

The calorimeter vessel holds about 5 lb. of water and is made of thin brass of size to hold the bomb conveniently immersed. A screw agitator works outside the bomb to bring all water to the same temperature and a finely divided thermometer is placed in the water. Outside the calorimeter shell is a layer of non-conducting material and occasionally the whole apparatus is enclosed by another vessel containing water to prevent radiation, as indicated in the figure.

Care should be taken that the ignition wire dips well into the coal, that the fuel, if anthracite, be powdered very fine, at least 100 mesh to the square inch, although bituminous coal may be somewhat coarser. Caution should also be taken to see that there is no leakage around the bomb. This can be detected by watching the gage after the bomb is filled with oxygen and the tank has been shut off. If there is a leak the pressure gage reading will drop gradually.

To use the apparatus, a gram, or 15.4 grains avoirdupois, of fuel is weighed and placed in a little porcelain dish which rests on the platinum disk at C. A fine iron wire is fastened to the electrode F and to the

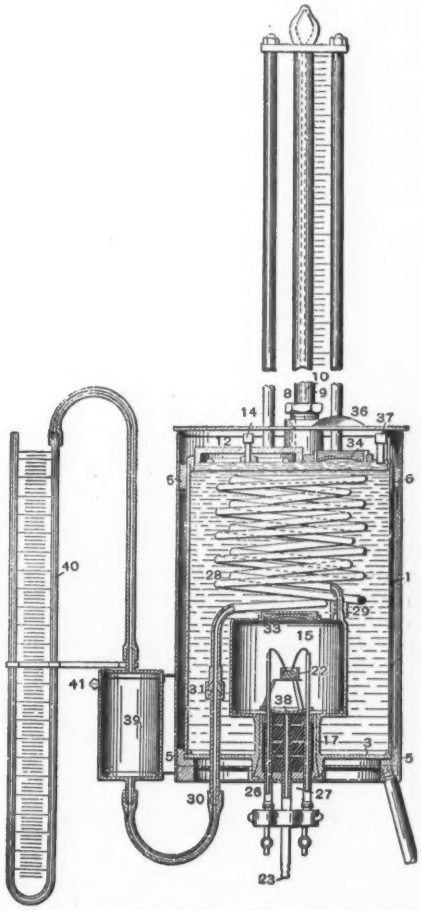


FIG. 2.—THE CARPENTER FUEL CALORIMETER

support of the disk. The cover is then put in place and firmly clamped down, joint with the bomb proper being made by a lead gasket.

The stopcock is now connected with the cylinder of oxygen O which is under 50 atmospheres pressure and the stopcock opened until the required pressure inside the bomb is obtained. The connection between cylinder and bomb is then broken and the bomb put into the calorimeter, the screw agitator and ther-

mometer adjusted and the calorimeter filled with water which has previously been weighed.

In handling the bomb after the dish has been filled with the fuel charge, care should be taken not to tip it sideways or to jar it, so that any of the fuel would be spilled out of the dish.

Stir the water and take observations with the thermometer to make sure of the initial temperature.

When this has been established, connections are made from the gas cylinder to the bomb and the battery to the electrodes. Current is passed through the electric circuit setting fire to the fuel. Thermometer readings are taken each half minute until the maximum temperature is reached, as shown by the temperature beginning to drop, and observations are continued long enough after the maximum to determine the rate of fall. When this has been established the test is finished.

The battery and gas cylinder are disconnected, the conical valve opened and the bomb removed from the calorimeter. The boiler is then washed out with distilled water to determine the weight of nitric acid. The correction for cooling is a factor expressing the rate of cooling per minute. This is determined by finding the drop in temperature from the maximum over a period of 5 or 10 min. and dividing the average fall in temperature during this time by the number of minutes. This will give the fall per minute. Multiply this by the number of minutes of the combustion period and it will give the loss in temperature due to cooling.

We have then this rule: Add the observed difference of temperature between original and maximum to the correction for cooling. Then add the weight of the water to the water equivalent of the bomb and other metal parts which will be given with the instrument. Multiply these two sums together and from the product subtract the sum of the weight of nitric acid times 0.23 and the weight of the iron wire times 1.6. The remainder will be the heat value in calories for 1 gram of the fuel. Multiplying this value by 1,800 gives the B. t. u. per pound.

The Carpenter Calorimeter

The Carpenter calorimeter is shown in sectional view in Fig. 2. In this a combustion cylinder, 15, is provided with a removable bottom, 17, through which the tube, 23, passes to supply oxygen. Also through this removable bottom the wires, 26 and 27, pass which carry electrical current to ignite the fuel. Above this removable bottom is carried the asbestos combustion dish, 22, which holds the fuel. For reflecting the heat upward from the bottom of the combustion cylinder a silvered mirror, 38, is provided, so that heat does not pass downward to any extent from the bottom of the combustion cylinder. Alternate layers of asbestos and vulcanite are fastened together to form the plug of this removable bottom and the whole thing is kept in place by a tight fit into the orifice.

Products of combustion pass upward through the spiral tube, 28, and then downward through 29, 31 and 30, to the small chamber, 39, which is connected on the outer end with an open U tube gage. The water in the chamber surrounding the combustion cylinder forms a bath which is connected with an open glass gage, 10, above the water chamber. A diaphragm, 12, above the water is used to adjust the level. From the small chamber, 39, a pinhole exit, 41, serves to allow the products of combustion to escape slowly. The outer casing is nickel plated and polished on the inside to prevent radiation of heat.

Five pounds of water are placed in the bath and the charge of fuel used is 2 grams. Coal which is to be tested is ground to a powder in a mill or mortar and the asbestos cup is heated through to drive off all organic matter. This cup is then weighed, the sample placed in it and the whole weighed together. The difference gives the weight of the coal used for the test. The cup is then placed in proper position on the bottom plug, which is inserted in the combustion cylinder.

Raise the ignition wire above the coal, turn on the current which will, of course, heat the air in the cylinder and cause the water to rise slightly in the glass tube. As soon as this commences turn on the oxygen and pull down the ignition wire to kindle the coal, at the same instant taking the reading on the glass scale.

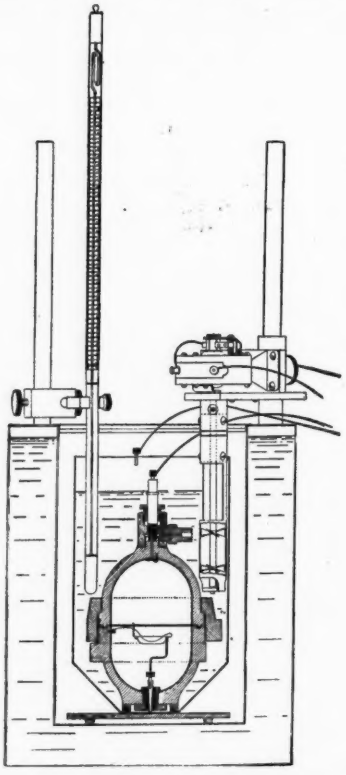


FIG. 3.—THE EMERSON FUEL CALORIMETER

Windows are provided in the top of the water chamber and the combustion cylinder so that the process of combustion can be watched and as soon as this is finished the scale reading and the time should be taken. The difference between the first and last readings taken will be the actual scale reading. This must be corrected for radiation.

To make this correction let the apparatus stand with the oxygen shut off as long as it took for the combustion to take place, then take the scale reading and the time. It is assumed that the drop in the scale reading during this time will indicate the amount of the radiation which took place during the combustion, and should, therefore, be added to the actual scale reading to give the corrected reading. With each calorimeter is furnished a calibration curve from which by comparison with the corrected scale reading the B. t. u.'s developed during the combustion can be found. The amount of ash is determined by weighing the asbestos cup after combustion. Dividing the num-

ber of B. t. u.'s developed during the test by the weight of coal burned in pounds gives the B. t. u. per pound. For ordinary every-day work this is one of the most convenient pieces of apparatus that has been devised, but does not show quite as accurate results in use as the Mahler.

Tests of liquid fuels are made in the same way as those for solid fuels, and the same calorimeters can be used for one class as for the other.

The Emerson Calorimeter

Another form of the bomb type is the Emerson, shown herewith.

A brief outline of the manipulation of the Emerson calorimeter is as follows: The lower half of the bomb is placed in a bench holder and the fuel pan and fuse wire placed in position as shown. One end of the wire is twisted into the hole in the right hand side of fuel pan and the wire extended across the pan through the hole in the mica, grounding on the bomb by means of the binding post, care being taken that the wire dips sufficiently to come in contact with the fuel. A known weight of fuel is placed in the pan. The upper half of the bomb is placed in position and the large nut brings it against a lead gasket inserted in a groove on the face of the lower half. The bomb is then ready to be filled with oxygen and this is admitted through the spindle valve at the top of the bomb. Oxygen is allowed to enter until the pressure reads 300 lb. per sq. in. when the spindle valve is closed. The bomb is now placed in the calorimeter which has been previously filled with 1900 grams of water.

With the stirrer moving, readings of the thermometer are taken every minute for 5 min., at the end of which time the fuel is ignited by the fuse wire and the temperature readings are continued while the temperature rises rapidly and for 5 min. after the maximum temperature has been reached. These temperature readings before and after the run proper give the data from which to compute the actual rise in temperature in the calorimeter if no radiation to or from the calorimeter has taken place. The product of this corrected rise in temperature times the weight of water plus the product of the rise in temperature times the "water equivalent" of the immersed parts of the calorimeter gives directly the calories per gram of the fuel in the bomb. From these figures, are computed the British thermal units per pound of fuel which is the result desired.

The Thompson Calorimeter

Another and somewhat simpler form of calorimeter for fuel analysis is the Thompson, shown in Fig. 4. This gives, however, only the approximate determination of the heat value and the results will not, therefore, check as closely as with the Mahler.

It consists of a glass cylinder A closed at the lower end to contain water, and a copper vessel B called the condenser, which is closed at the upper end with a copper cover having a metal tube C with a stop cock at the top. The lower end of B is opened and is perforated near the open end by a series of small holes. D is a metal base upon which B is fixed by 3 springs attached to D and pressing against the internal surface of B. A series of holes is made near the rim of D to assist in mixing the water and allow of easier raising.

Inside B is a copper cylinder, E, called the furnace, which is closed at the lower end only and fits into a metal ring in the center of D. The weight of water used is 967 times that of the fuel burned, so that the rise in temperature of the water in degrees Fahrenheit is equal to the number of pounds of water which 1 pound of the fuel will, theoretically, evaporate from and at 212 deg. F. Ten per cent is added to this number as a correction for the heat absorbed by the apparatus itself.

In operation 30 grains of finely powdered fuel is mixed with 10 to 12 times its weight of a perfectly dry mixture of 3 parts chlorate of potash and 1 part niter. This fuel mixture is carefully pressed into the furnace E and the end of a slow fuse about 0.5 in. long is inserted in a small hole made in the top of the mixture. The furnace is placed on the base, D, the fuse lighted and the condenser B with its stop cock shut is fixed over the furnace.

Previously the cylinder A has been charged with 29,010 grains of water, the temperature of which must be recorded; the condenser and base are now quickly placed in the cylinder and the fuse ignites the fuel mixture. The end of combustion will be shown by the ceasing of bubbles of gas rising through the water; the stop cock is opened so that water enters the condenser by the holes at the bottom and by moving condenser up and down, the water is thoroughly mixed so as to give it a uniform temperature. This is measured with a thermometer and recorded.

By adding 10 per cent to the rise in degrees Fahrenheit of the temperature of the water the theoretical evaporative power of the coal is approximately determined at once. The heating value in B. t. u. is found by multiplying this evaporative power by 967. This furnace works best with bituminous coals, but coke, anthracite and other more difficult combustibles can be tested by using a wider and shorter furnace and not pressing the fuel mixture down.

Testing Gas Fuels

The most satisfactory apparatus for measuring the calorific power of gas is the Junker calorimeter, as described in Gas and Fuel Analysis by Gill. It is portable, burns fuel at atmospheric pressure and can be operated continuously for any length of time. This apparatus has a combustion chamber, 28, surrounded by water jacket, 15, 16, through which pass a great number of tubes; the air space, 36, outside serves as a jacket to prevent radiation from the water bath. Thin copper is used for the construction in order to give rapid heat transfer.

Water for the jacket is passed in at 1, goes downward through 3, 6 and 7, and leaves the jacket at 21. The gases from combustion enter the tubes at 30 and pass downward, leaving at the bottom through the space 31 and passing outward through the outlet, 32, 33; water and gases, therefore, move in opposite directions, so that the hottest water comes in contact with the entering gases. The heat is practically all transferred from the gases to the water by the time that the gases reach the space 31.

Gas to be burned is metered and then passed into the apparatus through the cock, 22. A pressure regulator is introduced between the meter and the calorimeter to insure constant pressure, which makes the source of heat constant in quantity, and the water in the calorimeter is provided with 2 overflows so as to make the absorbing quantity constant. The thermometer at 12 measures the temperature of the entering water and one at 43 that of the water when leaving.

In order to determine the heating value of the gas four quantities are to be ascertained: (1) The number of cubic feet of gas burned; (2) the quantity of cooling water used; (3) the rise in temperature of the

cooling water; and (4) the quantity of water condensed from the exhaust gases.

In operating the calorimeter the cooling water is first allowed to flow through the upper overflow, then the water is allowed to pass through the calorimeter by opening the regulator, e, Fig. 5, near the bottom of the calorimeter. Gas is then turned on at the meter and lighted at the burner. The flow of gas should be such that 1 cu. ft. is burned in from 10 to 15 min. Next the cooling water should be regulated so that the increase in its temperature is only from 12 to 15 deg. The thermometers used in the cooling water are graduated to 0.1 deg.

When the required regulations are made and the temperature of the leaving cooling water is nearly constant, a run of 5 min. may be made and readings

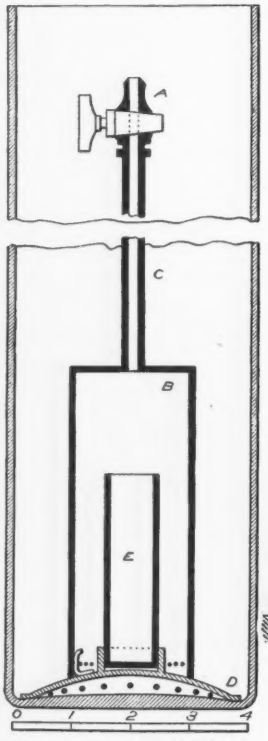


FIG. 4.—THE THOMPSON FUEL CALORIMETER

taken. Care must be taken to read the meter and the cooling water simultaneously. The temperatures of the entering and leaving water may be taken alternately each half minute so as to get their average values.

The heating value, H, of the gas may then be computed as follows:*

Water formed by the combustion of hydrocarbons collects from the exhaust gases at 34 and is drained off through outlet 35.

Under practical conditions the water formed by the complete combustion of hydrocarbons in the gas is not condensed and does not give up its latent heat of vaporization, but passes off taking with it its heat of vaporization.

The value of H, then, is too large and the "effective" value of the gas must be determined. To find the "effective" value, multiply the weight of condensed water in pounds by 966, divide the product by the number of cubic feet of gas and subtract the result from H, this new value H^1 is the "effective" value of the heating power of the gas in British thermal units.

Subtract the average temperature of entering water from that of the leaving water; multiply by the pounds of water used and divide by the cubic feet of gas used, reducing to standard conditions of temperature and pressure, 62 deg. F. and 30 in. mercury pressure.

The following determination of H^1 is from a sam-

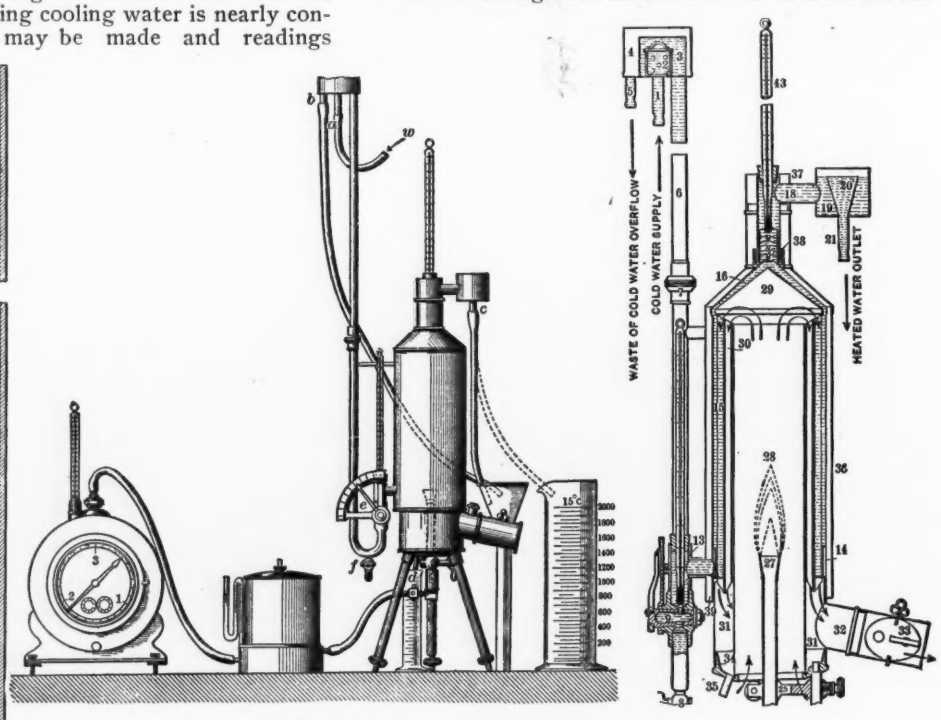


FIG. 5.—THE JUNKER GAS CALORIMETER; ARRANGEMENT AND SECTIONAL VIEW.

ple test: Cu. ft. of gas, 0.606; cu. ft. of gas (standard conditions), 0.598; No. of lb. of cooling water, 15.12; temp. of leaving water (average), 69.17 deg. F.; temp. of entering water (average), 44.47 deg. F.; temp. of room, 63.14 deg. F.; No. of lbs. of condensed water, 0.029.

$$H = (69.17 - 44.47)\ 15.12 \div 0.598 = 626 \text{ B. t. u.}$$
$$H^1 = 626 - (966 \times 0.029 \div 0.598) = 579 \text{ B. t. u.}$$

THE SARCO-BOMB FUEL CALORIMETER

Sarco Fuel Saving & Engineering Co., New York.

The Sarco calorimeter has been constructed upon the principles of the Mahler-Bomb, but its price is considerably lower than that of the older types, from which it differs materially in that all unnecessary complications have been avoided, errors, previously encountered, removed, and the whole constructed on engineering principles, making it adaptable to every day power plant use by the men in charge.

The bomb in which combustion takes place is made of special metal, which resists corrosion and has a high tensile strength; it is gold plated on the inside to withstand the action of the acids generated during

*As a formula

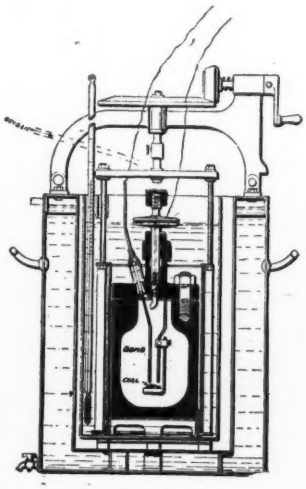
$$H = (t_1 - t_2)\ W \div V$$

in which t_1 and t_2 are the average temperatures of the cooling water, W is the weight in pounds of the cooling water, and V is the number of cubic feet of gas reduced to standard conditions of temperature and pressure.

combustion. The bomb is lined by a triple process consisting of an electric deposit of tin, upon which pure gold is laid by means of a special amalgam process, the surface being finished off by a thin coating of platinum. It is fitted with a cover fastened down by 3 studs and nuts, the joint between the body of the bomb and the cover being made with thin lead wire. The cover has a screw valve attached, which regulates the introduction of compressed oxygen from an ordinary gas cylinder.

Inside the bomb is a crucible, in which is placed the fuel to be burned. The electrodes to convey the current are connected by a fine wire which serves to ignite the fuel, when connected with a battery. One of the electrodes is insulated by a porcelain collar where it passes through the cover of the bomb.

The bomb is placed inside a vessel containing a known weight of water, which is stirred by an arrangement of paddles to ensure a uniform tempera-



THE SARCO BOMB-FUEL CALORIMETER

ture. This vessel is placed in the interior of an annular receptacle which acts as a water jacket. There is an air space between the inner vessel and the water jacket, thus forming a heat insulator, while the latter prevents heat reaching the calorimeter from external sources. A highly sensitive thermometer, divided into tenths of a degree, is provided for taking the temperatures required.

A known amount of the fuel to be tested is placed in the crucible inside the bomb, the cover of which is bolted down. By means of the screw valve on the bomb cover, connection is made with a cylinder containing compressed oxygen, and the interior of the bomb is thus filled with oxygen under high pressure.

The bomb is then placed inside the inner or calorimeter vessel, which contains a known weight of water. The fuel is now fired by connecting the electrodes with the battery, and combustion takes place in the bomb. The heat thereby evolved is imparted to the water surrounding the bomb, by conduction through its walls, and the rise in the temperature of the water is noted. Knowing the water equivalent of the apparatus, the calorific value of the fuel under test is then obtained by the standard rule given for the Mahler-Bomb calorimeter.

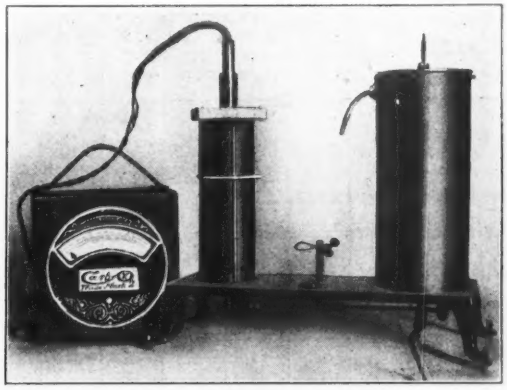
FUEL TESTS OF THE new battleship North Dakota during a 24-hr. run show that besides being speedy it has good efficiency in the matter of fuel consumption.

AUTOMATIC GAS CALORIMETER

Carb-Ox Co., Chicago, Ill.

The importance of a continuous check upon a gas producer is recognized by everybody who owns and operates one. The apparatus illustrated herewith indicates and records the heat value of producer gas and illuminating gas, or any other commercial gas, continuously, the smallest fluctuation in the quality of the gas being registered. The principles upon which the apparatus is designed are quite simple and the machine itself in general organization is as follows:

A special burner is provided and gas is fed to this burner at constant volume, pressure and temperature. The burner is also supplied with air at constant humidity, volume and temperature. The burner is enclosed in an insulated retort and the temperature of the products of the combustion of the gas is taken by means of a thermocouple and galvanometer. The temperature of the resulting products depends of course upon the heat units released as the gas is burned, and the temperature scale of the galvanometer is paralleled by a corresponding scale in terms of heat units.



THE CARB-OX GAS CALORIMETER

The man in charge of the gas producer is immediately notified by this instrument of the slightest change in the quality of the gas. If the gas should be deteriorating he will have sufficient notice to enable him to locate the cause of the trouble and correct the difficulty in time to avoid a shut down. It is built in 2 models, as an indicator and as an indicating and recording machine.

SPACE REQUIRED for storing various fuels may be found from the following data: anthracite coal, solid, weighs 93 lb. per cu. ft., and 54 lb. loose; bituminous coal weighs 84 lb. solid, and 49 lb. loose; a heaped bushel of loose bituminous coal weighs 74 lb; loose coke weighs 27 lb. per cu. ft.

FRICTION OF FLOW of gases in various parts of ordinary horizontal tubular boiler, setting and stack, is as follows:

	In. water
Entrance velocity of air to ash pit 3.6 ft. per sec.	0.002
Grate and fire resistance	0.175
Combustion chamber and flue resistance	0.237
Breeching resistance	0.016
Stack, 75 ft. high, resistance	0.037
Discharge velocity, 11 ft. per sec	0.017
Total draft pressure required	0.484

PURCHASING COAL ON SPECIFICATION

GETTING WHAT YOU WANT AND PAYING FOR WHAT YOU GET

AS INDICATED in the discussion on coal values and testing, the tendency now is to buy coal by the heat units contained rather than by weight of material delivered. The leader in this movement has been the United States government, although many private concerns are taking up the matter and one company in Chicago and another in Boston makes it a regular business to draw up the specifications on which coal shall be bought and then to test the coal to insure that it comes up to these specifications. In the case of anthracite the government awards contracts for coal to the highest responsible bidder.

Anthracites are so even in quality that the variations are only such as can be taken care of by deductions and bonuses from contract price. The specifications are made part of the contract and the prices adjusted on the basis of the cost of 1,000,000 B. t. u. For bituminous coal the bidder offering the best coal for the lowest price is given the contract. Coal which proves on test to be of better quality than specified is given a bonus proportional to its increased value. Coal of poorer quality than standard has deductions made from the contract price proportional to the decrease in value.

This system has the advantage of putting bidders on a competitive basis as to the actual usable heat value, and broadening the field of competition because trade names and locations of mines are ignored. The buyer is insured against paying for the ash in poor and dirty coal, yet on occasion a coal which is below the standard may be accepted and paid for without injustice to the buyer and without cancelling the contract.

Foreign Matter

The materials in coal which cause it to be above or below standard are usually the ash and the moisture, both of which cut down the effective heating value, in some cases so much that the lignites high in moisture and high in ash may be unavailable for boiler fuels, although being still possibilities for the gas producer.

The coal as received must be the basis of payment, but reports of testing of coal should be made out, giving the heat value not only as received, but also per pound of dry coal, in order to determine fairly the quantity of ash. The moisture in coal may vary widely according to weather conditions or the incidents of shipping, and ash computed as a percentage of the wet coal as received may be quite low, whereas when figured as a percentage of the dry coal it may be quite high.

Sulphur, if present in the free state, or, as is more common, when combined with iron or other elements, often forms a clinker which greatly increases the labor of handling the furnace. More than 5 per cent of sulphur will cause difficulty with clinker, but a little steam introduced under the grate will frequently remove much of the trouble from this source.

As a result of the government experience, it is stated by John S. Burrows, in Bulletin 378 of the Geological Survey, that in general in any market the coal obtainable at the lowest price is the most economical "provided that the furnace equipment is suited to the coal." If this furnace equipment is not so suited, it will usually pay to change it so that it will fit the cheapest fuel available. He says:

"In the purchase of coal, then, attention should be given to the character of the furnace equipment and the load; the character of coal best suited to the plant conditions; the number of heat units obtainable for a unit price; the cost of handling the coal and ash, and the possibility of burning the coal without smoke or other objectionable features."

PERCENTAGES OF ASH AND CORRECTION IN PAYMENT; GOVERNMENT SPECIFICATIONS FOR ANTHRACITE

SIZE COAL	6.01 TO 6.50	6.51 TO 7.00	7.01 TO 7.50	7.51 TO 8.00	8.01 TO 8.50	8.51 TO 9.00	9.01 TO 9.50	9.51 TO 10.00	10.01 TO 10.50	10.51 TO 11.00	11.01 TO 11.50	11.51 TO 12.00	12.01 TO 12.50	12.51 TO 13.00	13.01 TO 13.50	13.51 TO 14.00
	CORRECTION IN PRICE PER TON CENTS															
FURNACE & EGG	+24	+20	+18	+15	0	0	0	0	0	0	0	0	−15	−18	−21	−24
STOVE	—	—	—	+27	+24	+21	+18	+15	0	0	0	0	0	0	0	0
CHESTNUT	—	—	—	—	—	—	—	+27	+24	+21	+18	+15	0	0	0	0
PEA	—	—	—	—	—	—	—	—	—	—	—	—	—	+15	+18.5	+10

SIZE COAL	14.01 TO 14.50	14.51 TO 15.00	15.01 TO 15.50	15.51 TO 16.00	16.01 TO 16.50	16.51 TO 17.00	17.01 TO 17.50	17.51 TO 18.00	18.01 TO 18.50	18.51 TO 19.00	19.01 TO 19.50	19.51 TO 20.00	20.01 TO 20.50	20.51 TO 21.00	21.01 TO 21.50	21.51 TO 22.00
	CORRECTION IN PRICE PER TON, CENTS															
STOVE	−15	−18	−21	−24	−27	—	—	—	—	—	—	—	—	—	—	—
CHESTNUT	0	0	0	0	−15	−18	−21	−24	—	—	—	—	—	—	—	—
PEA	+7.5	+5	0	0	0	0	−5	−7.5	−10	−12.5	−15	—	—	—	—	—
BUCKWHEAT	—	+12	+10	+8	+6	+4	0	0	0	0	−4	−8	−14	−21	−32	−48

Allowable Ash in Anthracite

In buying anthracite coal the size should, of course, be fixed in the specifications, as the smaller sizes are cheaper than large ones, due to the demand for large sizes for domestic use. The standards adopted by the government are those given in a previous table which have been adopted as standard.

The percentage of ash in dry coal is also fixed, the following being the percentages allowed: Furnace coal 10 per cent, egg coal 10 per cent, stove 12 per cent, chestnut 14 per cent, pea 16 per cent, buckwheat No. 1 or No. 2, 18 per cent. Coal with less ash than this is paid for at a higher price than the contract and more ash than this results in a deduction down to the

point where a greater percentage causes rejection. This point is for furnace coal 14 per cent, egg coal 14 per cent, stove coal 16 per cent, chestnut 18 per cent, pea 20 per cent, buckwheat No. 1 or 2, 21 per cent. This is the percentage of dry coal as a basis, and dry coal is defined as coal free from moisture as determined by drying a small sample at 220 deg. F. These specifications are wide enough to permit the furnishing of any coal where reasonable care is used in picking out slate, bone, etc. For anthracite coal the white ash and red ash are both allowed, but must be bid on separately.

Sampling is done by the method given in the article on estimating coal values, the provision being that in the sample taken to the laboratory for testing none of the fragments shall exceed 0.5 in. in diameter. The sampling must be done as rapidly as possible and the analysis in the laboratory made as soon as possible after receipt of the coal. Tests of coal are to be made according to the method adopted by the American Chemical Society, the heat value being determined by the Mahler bomb calorimeter.

The table herewith shows the additions or deductions to be made for ash in anthracite coal on the different sizes.

Bituminous Coal

Specifying bituminous coal, the method of sampling is the same as for anthracite and the government blank states the maximum amount of ash, volatile matter, sulphur, dust and coal ⅛ in. in diameter or under which will be allowed.

Causes for rejection are excessive clinkering and prohibitive amount of smoke, excess of sulphur or dust, or an excess of ash, the prices to be corrected for variation in ash according to Table II herewith. The first column shows the amount of ash in the coal as per contract. No deduction is made for an amount shown in the second column. If the ash runs above that limit deductions are made according to the figures shown in the rest of the table, and if the ash reaches an amount to the right of the black line the coal is rejected. For instance, a coal specified to have 10 per cent ash would have no penalty up to 12 per cent. If, however, it had 14.5 per cent of ash, 7c a ton would be deducted from the contract price, and if it had 17 per cent of ash it would be rejected.

In general the letting of contracts according to these specifications has resulted in a lowering in the percentage of ash and increasing the B. t. u. per ton. Some examples from the experience during the year 1909 are as follows:

In Boston a coking run-of-mine coal was specified to have 8 per cent ash, 22 per cent volatile, 1.5 per cent sulphur. A Cambria county, Pa., coal was bought and had 7.12 per cent ash, with heat value of 14,257 B. t. u., as received. The contract price bid was $4.43 a ton, and it was adjusted to the lowest ash, paying $4.47. The cost per 1,000,000 B. t. u. as bid was 13.997 cents and the actual cost was 13.872 cents.

In Toledo, coal was asked for having 8 per cent ash, 22 per cent volatile and 1.5 per cent sulphur, and a Pocahontas coal was supplied, the ash in dry coal being 4.45 per cent, the heating value 14,900 B. t. u. and the price bid $3.95. A price of $3.9548 was paid, making the actual cost 11.834 cents per 1,000,000 B. t. u.

In St. Louis a coal was specified with 12 per cent ash, 43 per cent volatile and 3 per cent sulphur. Coal from St. Clair county, Illinois, was supplied which tested out 12 per cent ash and heating value of 10,500, price bid per ton was $2.04, and this was adjusted to $2.1252, making the cost 8.6735 cents per 1,000,000 B. t. u.

A method of purchase adopted by the Charles River Basin Commission of Massachusetts called for the statement of the ash in the coal and the price was corrected for variation of the ash more than 2 per cent either way from this standard, and for sulphur more than 1 per cent. If the ash was from 2 to 2.5 per cent above or below the standard 15 cents a ton was deducted or added to the contract price. For each additional 0.5 of 1 per cent or fraction thereof over the 2.5 per cent variation, 3 cents a ton additional was deducted or added respectively, this continuing up to a maximum of 14 per cent ash. For each 0.5 of 1 per cent or fraction above 14 per cent ash, 6 cents a ton additional was deducted. For sulphur 0.01 of 1 per cent in excess of 1 per cent caused a deduction of 0.5 cent a ton from the contract price.

PERCENTAGES OF ASH, BITUMINOUS, AND PAYMENT CORRECTION

Ash as established in proposal (per cent).	No deduction for limits below—	Cents per ton to be deducted. 2	4	7	12	18	25	35	Maximum limits for ash (per cent).
		Per cent of ash in dry coal.							
5	7	7- 8	8- 9	9-10	10-11	11-12	12-13	13-14	12
6	8	8- 9	9-10	10-11	11-12	12-13	13-14	14-15	13
7	9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	14
8	10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	14
9	11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	15
10	12	12-13	13-14	14-15	15-16	16-17	17-18	.....	16
11	13	13-14	14-15	15-16	16-17	17-18	18-19	.....	16
12	14	14-15	15-16	16-17	17-18	18-19	19-20	.....	17
13	15	15-16	16-17	17-18	18-19	19-20	20-21	.....	18
14	16	16-17	17-18	18-19	19-20	20-21	21-22	.....	19
15	17	17-18	18-19	19-20	20-21	21-22	.....	.....	19
16	18	18-19	19-20	20-21	21-22	22-23	.....	.....	20
17	19	19-20	20-21	21-22	22-23	.....	.....	.....	21
18	20	20-21	21-22	22-23	.....	.....	.....	.....	22

This establishment of the bonus and deduction which shall be made and the limits which shall cause rejection will, of course, depend upon the fuel available in any market. For instance, the United States rejects anthracite coal having sulphur in excess of 1 per cent and bituminous having it in excess of from 1.5 to 3 per cent, depending on location, while, as already stated, the Charles River Commission puts a penalty price on sulphur in excess of 1 per cent.

The Cleveland Railway Co., using Ohio bituminous slack establishes the normal sulphur as 3.5 per cent and puts a penalty of 2 cents a ton for sulphur between 4 and 4.4 per cent, ranging up to 30 cents a ton for sulphur from 10 to 10.4 per cent. The Interborough Co. of New York penalizes coal carrying more than 1.5 per cent of sulphur, deducting 6 cents for a sulphur content between 1.5 and 1.75 per cent.

As to ash, the government regulations have already been stated and the Third Avenue Railroad in New York fixes the standard ash for No. 1 buckwheat at 17.5 per cent and exacts penalty above 18 per cent. Between 18 and 23 per cent the penalty is 2 cents a ton for each 0.5 of 1 per cent in excess and above 23 per cent the penalty is 3 cents for each 0.5 of 1 per cent excess, but no premium is allowed for less ash than the standard.

One of the most effective methods of keeping down moisture is that adopted by the Third Avenue Railroad Co., which deducts from the railway scale weights to be paid for an amount equal to all moisture in excess of 4 per cent with bituminous coal and 3 per cent with anthracite. The New York companies set one peculiar limit, viz., on the amount of volatile matter. This is because the volatile matter often contains some useless gases and an excess of volatile makes it difficult to burn the coal efficiently and without smoke. The limit of volatile set varies with the kind of coal,

but a 5 per cent variation above standard brings a penalty of 2 cents a ton for every 0.5 of 1 per cent.

Illinois Coal Raw and Washed

When buying Illinois coal it should be remembered that the average heat value, as shown by tests made at the University of Illinois experiment station, is 14,319 B. t. u. per pound of dry coal. Of all the coals tested but few of them vary more than 2 per cent from this amount. As to washing of coal, it was found that when raw coal contains 8 per cent ash, 20 per cent of this is removed by washing; for raw coal 12 per cent ash, 30 per cent is removed; for 16 per cent 43 per cent is removed; for 20 per cent 53 per cent is removed.

Washing also removes a considerable portion of the sulphur. When the raw coal contains 2 per cent, the reduction by washing is 13 per cent; for 3 per cent sulphur the reduction is 17 per cent; for 4 per cent the reduction is 22 per cent, and for 5 per cent the reduction is 28 per cent. It was found that the material thrown out by the washing jig is ⅔ coal and ⅓ noncombustible refuse.

For Illinois coal, the same as for others, the evaporative efficiency decreases as ash and sulphur increase, each additional 1 per cent of ash and sulphur resulting in a decrease in efficiency of 0.4 of 1 per cent. The Illinois tests confirmed others in regard to the briquetting of coal, viz., briquetting does not pay from an efficiency standpoint except when the raw coal is in the form of slack or screenings.

SMOKELESS OPERATION OF BOILER PLANTS

CONDITIONS TO BE FULFILLED AND SOME EXAMPLES FROM PRACTICE

By Lewis Sanders

SMOKELESS operation of the boiler plant is now one of the essentials of its proper management. Comparatively few years ago plants were allowed to smoke ad libitum with practically no criticism, but with the general movement throughout American cities to pay attention to the beautification of the city, as well as its commercial development, the smoking chimney has come in for serious criticism as one of the greatest factors in detracting from a pleasing appearance.

Not only is it in itself unsightly and unhealthy but it rapidly destroys the beauty of any architectural

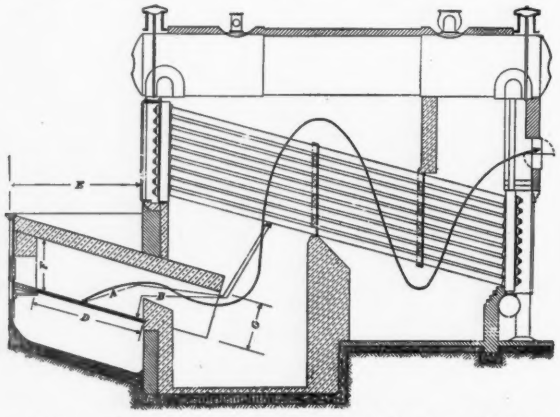


FIG. I.—HAND FIRED FURNACE FOR B. & W. BOILER

works, and even seriously injures interior decorations. The movement to beautify cities, which started in purely aesthetic aspirations, has become very much stronger since the business community has awakened to the fact that a beautiful city is a commercial asset that brings returns that amply warrant the investment. The smoking chimney must go, not only because it is unsightly in itself, but primarily because it interferes with the efforts of the community to improve appearances.

Smoke Costs Money

The power plant owner should lend his strongest co-operation in the abatement of the smoke nuisance, because he owes it to the community at large, on whose rights he is infringing when producing smoke, and also for the more selfish although more influential reason that he can save money for himself by doing so. Black smoke is without exception an indication of improper combustion, due either to wrong furnace construction or wrong handling of the fires, and the power plant owner pays for this in increased coal bills. If the majority of power plant owners realized exactly how much they were paying annually for the privilege of painting the air black they would abate their own smoky chimneys with much greater vigor and thoroughness than that of any municipal smoke inspector.

Principles of Complete Combustion

The principles of proper combustion are very simple, are generally understood among engineers and are usually completely ignored in practice.

The combustion of coal in boiler furnaces consists of the feeding of the coal into the furnace; the bringing of the coal to the ignition temperature together with the proper quantity of air for its combustion, and the thorough mixture of the combustible gases generated during this process, at the same time keeping them at a sufficiently high temperature to permit the continuance of the combustion. The gases after being completely burned have their heat absorbed by the boiler. The boiler is essentially a hot air heating apparatus and Direct Flames Should Never Touch It, a condition however, frequently not observed. The process of burning the coal is completed with the removal of the ash from the grates.

In burning anthracite coals there is no smoke problem to consider for the reason that they contain little volatile matter and no gases are driven off from them, the entire process of combustion taking place in the fuel bed and within a few inches above it; the fuel bed itself performing the functions of thoroughly mixing the air and combustible, while the air is passing through the bed, and maintaining the high temperature necessary to insure complete combustion.

How Soft Coal Burns

With bituminous coals, an entirely different condition is encountered. From 17 to upwards of 50 per cent of such coals is volatile matter, depending on the coal deposit from which they have been mined; that is, if such coals are heated at a point below their ignition temperature they would distil from 17 to 50 per cent of their weight as gas, this gas being com-

posed of various hydrocarbon compounds, the exact nature of which is not known owing to the many rapid reductions occurring from one series of compounds to another during the process of distillation.

When a shovelful of such coal is thrown on a bright fire, the coal is rapidly heated and begins at once to distil large quantities of gas. This gas, it must be noted, is generated entirely at the upper surface of the fuel bed where there is no air to come in contact with it to cause combustion, therefore the entire mixture of the air and combustible gas, and their combustion must take place above the fuel bed. This results in the production of long flames necessitating a large combustion chamber and proper mixing arrangement to permit of complete combustion before the gases strike the boiler proper. This is the more necessary as we have no such aid to rapid mixing of the gases as is afforded by the particles of coal in an anthracite fire which both break up and heat the streams of air.

We cannot give a better description of what takes place in a bituminous coal fired furnace than to quote from Kent's Steam Boiler Economy.

"The first thing that the fine fresh coal does is to choke the air spaces existing through the bed of coke, thus shutting off the air supply which is needed to burn the gases produced from the fresh coal. The next thing is a very rapid evaporation of the moisture from the coal, a chilling process, which robs the furnace of heat.

"Next is the formation of water-gas by the chemical reaction, $C + H_2O = CO + 2H$, the steam being decomposed, its oxygen burning some of the carbon of the coal to carbonic oxide, and the hydrogen being liberated. This reaction takes place when steam is brought in contact with highly heated carbon. This is also a chilling process, absorbing heat from the furnace. The 2 valuable fuel gases thus generated would give back all the heat absorbed in their formation if they could be burned, but there is not enough air in the furnace to burn them.

"Admitting extra air through the fire-door at this time will be of no service, for the gases being comparatively cool cannot be burned unless the air is highly heated. After all the moisture has been driven off from the coal, the distillation of hydrocarbons begins, and a considerable portion of them escapes unburned, owing to the deficiency of hot air, and to their being chilled by the relatively cool heating surfaces of the boiler.

"During all this time, great volumes of smoke are escaping from the chimney, together with unburned hydrogen, hydrocarbons and carbonic oxide, all fuel gases, while at the same time, soot is being deposited on the heating surface, diminishing its efficiency in transmitting heat to water."

In properly constructing and operating a soft coal furnace so as to be smokeless and efficient, when hand fired, the chief difficulty is the intermittent character of the operation, the conditions not remaining constant for a moment. A comparatively large quantity of fresh coal is fired, putting great demands on the furnace for an immediate supply of air above the fuel bed, at a high temperature. This demand steadily decreases until the fire is in the condition of a coke fire, requiring that practically all of the air go through the fuel bed and none above it. It is obvious that the smaller the quantity of coal that is fired at one time and the more frequently the firing done, the less the change that is produced in the furnace conditions.

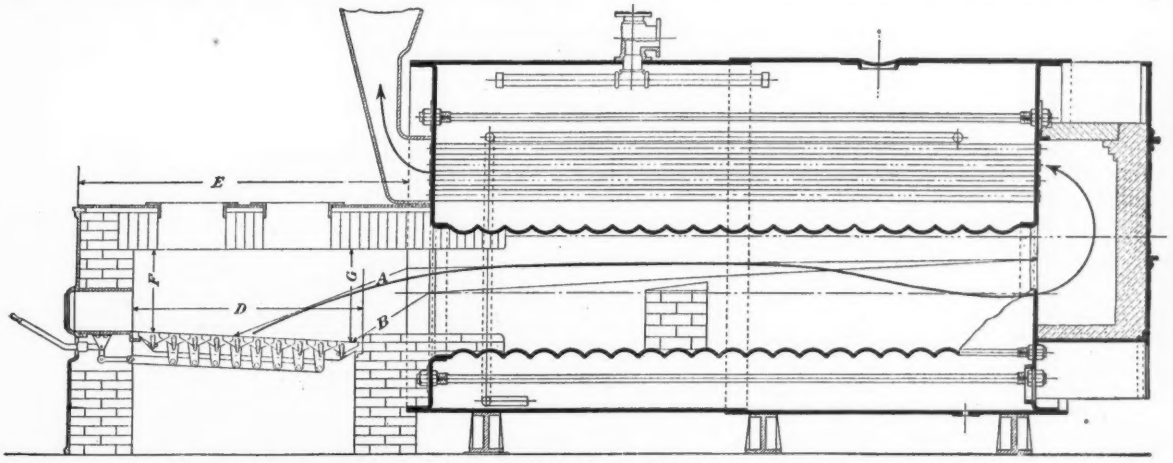


FIG. 2.—HAND FIRED FURNACE WITH SHAKING GRATE FOR SCOTCH MARINE BOILER

Conditions for Non-Smoking

The first requirement of the furnace when fresh coal is charge, is an extra supply of air introduced above the fuel bed and this air should be as warm as possible, otherwise, it will produce a chilling effect in the combustion zone. Second, the air must be intimately mixed with volatile gases distilled from the fresh coal. Third, they must be kept well above the ignition point. Fourth, they must remain in the hot combustion chamber for a sufficient length of time to complete the combustion.

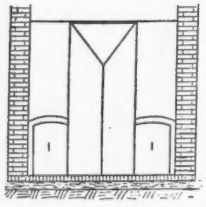
Speed of Flame Travel

Observations taken by the U. S. Geological Survey, at the fuel testing plants, indicate that the average time taken by the gases in passing through the combustion chamber of an ordinary furnace is about one second. To increase the combustion space sufficiently to produce smokeless combustion is therefore not practical, as if size alone were depended upon, the furnace would be of prohibitive dimensions. As flame will travel through a perfect mixture of explosive gases, at a rate of 1,000 ft. a second, it is apparent that even so small a period of time as a second will suffice for the complete combustion of the gases from the coal, provided they are thoroughly mixed with the air. Proper mixing arrangements within the furnace are, therefore, the most important feature in securing smokeless combustion.

Steam Jets as Mixing Devices

Steam jet devices have been among the most popular for this work. They are, however, merely a makeshift proposition and are rather a barbarism. The introduction of the steam itself is distinctly detrimental, as it not only has a chilling effect on the combustion zone, but also carries considerable additional heat up the stack. They are costly devices to operate, although their installation is in some cases quite justified, as, when installed with furnaces that have sufficient combustion chambers, well protected with fire brick, they do greatly reduce the smoke and may increase the economy more than enough to compensate for the steam they consume.

They are frequently misused, however, and are often installed under boilers where they are nothing but a source of loss, because the combustion chamber is such that no amount of mixing can produce good results. The writer has seen them installed on Manning boilers, in which the fire chamber is the most unsuitable that could possibly be designed for coals carrying high percentages of volatile matter, although a perfectly good furnace for suitable coals. In the combustion chamber of the Manning boiler, the steam jets do not appear to have the slightest effect in reducing the amount of smoke produced, and the steam that they use is simply a loss to the plant.



Numerous claims have been made for devices introducing highly superheated steam into the combustion chamber. Superheating steam, in this case, simply minimizes the bad effects of saturated steam in cooling the combustion chamber; it is otherwise of no benefit whatever.

Hand Fired Furnaces

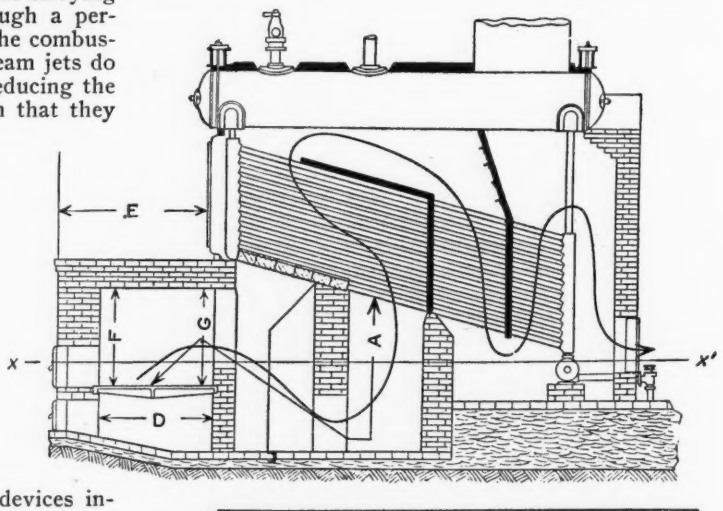
In a hand fired furnace it is necessary that the mixing devices and a considerable part of the combustion chamber be beyond the grate surface, because the coal that is charged on the rear of the grates would otherwise distil its gases without giving any opportunity either to mix or burn them. It is not practical to give dimensions of combustion chambers necessary to produce smokeless combustion, because so much depends on the efficiency of the mixing devices and the means for introducing air properly heated in the combustion zone. A furnace that would be adequate in size with one arrangement of mixing baffles would be entirely inadequate with some other system.

Results With Oil

That the mixing and uniformity of conditions are the 2 important factors is shown by the results on oil fired furnaces where the entire fuel is volatile matter, which, if fired under the conditions of an ordinary bituminous coal furnace would produce such dense smoke as to require a revision of the smoke inspectors' charts. But oil permits of the most intimate and complete mixture of the air and combustible and also an absolutely uniform set of conditions, the result being that smokeless combustion is obtained with a less excess air than with any other fuel, and a higher percentage efficiency can be obtained from the boilers.

So complete is the mixture of oil and air, that oil fired furnaces properly constructed with adequate baffling, can be run with as little as 5 per cent excess air, over the theoretical required for complete combustion, without the formation of any appreciable quantity of carbon monoxide.

With a coal fired furnace, on the other hand, the difficulties of intimately mixing the air and combustible are so much increased that it is necessary to have from 40 to 50 per cent excess air in order to prevent the formation of CO. It should not be inferred that the remedy for a poorly constructed furnace is the introduction of still larger quantities of air, because this will cause a reduction of temperature in the combustion zone which will tend to produce smoke. If a furnace cannot be operated smokelessly with from 40



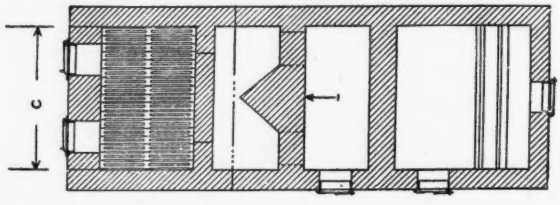


FIG. 3.—DUTCH OVEN FURNACE WITH MIXING WALL

to 50 per cent excess air, it is either being wrongly fired or the furnace itself is unsuited for the coal used.

The accompanying illustrations of hand fired furnaces for highly volatile coals are taken from bulletin No. 373 of U. S. Geological Survey. In some of them, the designers have depended on getting a long flame passage surrounded by fire brick before reaching the boiler tubes. Others have depended more on baffling devices to thoroughly mix the gases while still others have combined the 2. The type of furnace, such as Figs. 1 and 2, depending on long flame chambers are most suited for the coals rather low in volatile matter, as they will generally provide sufficient mixing in connection with the length of combustion chamber, to prevent the formation of smoke.

Where the coal is sufficiently low in volatile matter, this type of furnace should be preferable as being less costly to maintain than baffling, as, on account of

the intense heat and the direct action of the flames to which the latter is subjected, it is naturally higher in cost of repairs. As the percentage of volatile matter increases, it is necessary to resort more and more to baffles until with the most volatile coals we require a furnace combining both baffling and extra long combustion chambers, similar to those shown in Figs. 3 and 4.

Stokers and Smokelessness

Stokers are unquestionably the proper method of handling highly volatile coals. With a stoker fired furnace we have 2 conditions required for smokeless combustion partly fulfilled. Uniformity of conditions is completely met by the continuous feed of a stoker, so that conditions change only with change of load and the change is then only quantitative and not qualitative. The coal being fed in regularly at the front or side or center of the fire, according to the type of stoker used, distils its volatile gases at one point in the fire, and these gases then pass over a bed of fuel, consisting practically of incandescent coke, serving to keep them at a high temperature and also permitting utilization of almost the whole of the combustion chamber for mixing and burning the gases, which is not the case in a hand fired furnace where gases are distilled over the entire fuel bed.

A much smaller quantity of air has to be introduced above the grates in a stoker than in a hand fired furnace, because the greatest resistance to the admission of the air exists at a point where the coal is fed in, consequently the draft can be carried at a point such that a sufficient quantity of air will be driven through the partly burned coal, where the resistance is less, to consume the gas distilled from the raw coal. Air introduced through the fuel bed in this way has the advantage of being highly heated and broken up into numerous streams, so as to mix with the combustible gases. It is necessary, of course, that a stoker be provided with an adequate fire-brick combustion chamber, and proper baffling devices. For the more volatile coals a certain amount of air must be introduced above the fire, but a careful regulation of drafts and depth of fuel would very much decrease the amount necessary to introduce in this way.

Careless Handling of Stokers

Good results possible to be obtained from stokers are all too frequently nullified by careless operation. Unskilled firemen have a tendency to poke and bar the fires on the grates on the slightest provocation, almost always without any necessity for so doing and generally with detrimental results. They do it because it requires less mental effort than to regulate the stoker properly. although it requires far more physical effort. The writer has seen numerous chain grate stokers operated with the rear third of the grate covered with burnt out cinder, through which large quantities of air were blowing, carrying away heat up the stack. Other types of stokers are run quite as poorly by firemen who fail to keep them properly adjusted on coal feed and grate movement.

Summary of Conditions for Smokelessness

The conditions necessary to the successful operation of a boiler plant, smokelessly, may be summarized as: establishing a firing system that gives as close an approximation to uniformity of conditions as is permissible; the provision of fire-brick lined combustion space, properly baffled; the introducion of sufficient heated air in the combustion zone thoroughly to mix with and consume the gases driven off from the coal. The introduction of this air should be automatically controlled, so as to gradually diminish after each opening of the fire doors. There are numerous devices on the market for this purpose. All baffling devices, such as fire-brick piers, should be of massive construction, as light construction would soon be destroyed by the intense heat.

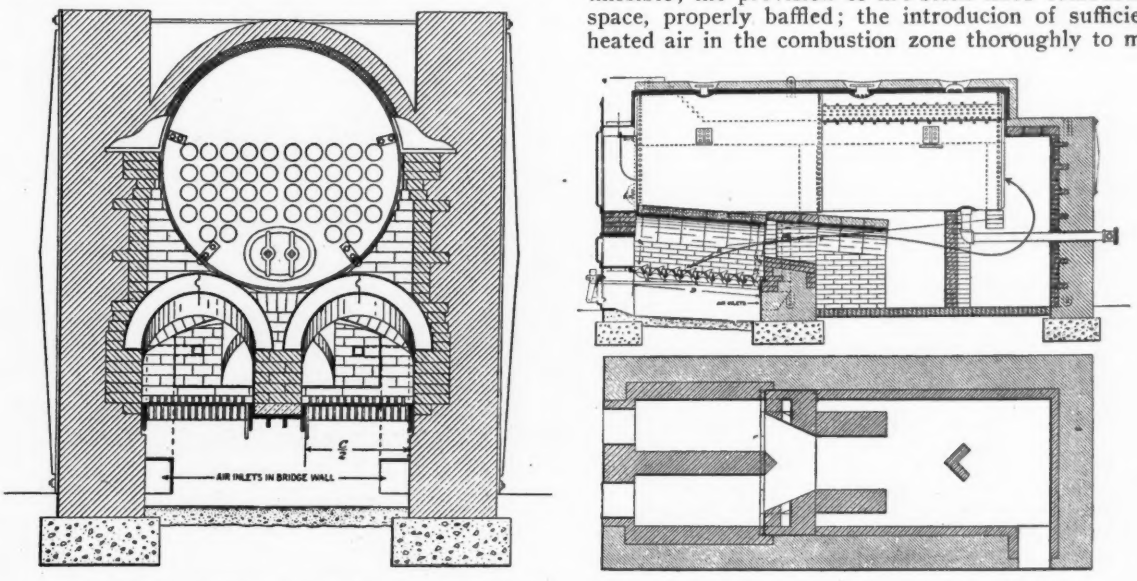


FIG. 4.—DOUBLE ARCH FURNACE WITH MIXING ARCH FOR RETURN TUBULAR BOILER SETTING

THE CHIMNEY OF THE L. S. STARRETT CO.'S PLANT

We are informed by the M. W. Kellogg Co., manufacturers of radial brick chimneys, that the article on the L. S. Starrett power plant in our issue of December was in error in making the statement that the chimney was Custodis. This chimney is of radial brick, built by the M. W. Kellogg Co., of New York City, and the credit for this very creditable piece of work should properly go to the Kellogg Co. Our information came from a source which seemed safe, but as we were wrong, we are glad to make this acknowledgment of it.

THE FURNACE IN DETAIL

ITS PARTS AND WHAT EACH SHOULD ACCOMPLISH

CONSIDERING the furnace as a means for generating all possible heat from a given fuel, there must be a place on which the fuel can rest, means for supplying air to permit of combustion, space for taking away the refuse from the fuel bed, and space for burning the gases which are distilled from the fuel. The fixed combustible will, of course, burn on the grate, but the volatiles will escape as hydro-carbons or hydrogen and must be burned after they leave the fuel bed. We can consider, then, the different parts of the furnace proper, leaving out special devices for insuring good combustion, as the ashpit, the grate, the firebox, the bridge wall and the combustion chamber, and it is worth while to consider briefly each of these to see just what function it performs in furnace operation.

Ashpit

The ashpit is not merely a place in which to dump ash and clinker and from which to take these away, but

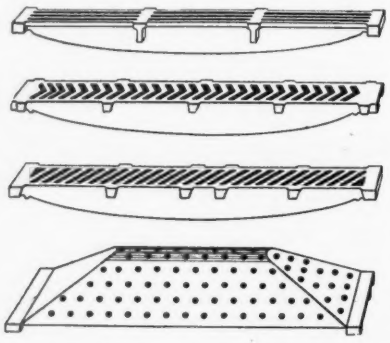


FIG. 1.—GRATE BARS; ORDINARY, HERRINGBONE, TUPPER AND SAWDUST FORMS

serves also the purpose of an air passage and must, therefore, be of such area and shape as will allow plenty of air to reach the underside of the fuel bed and will permit of this air being distributed evenly to all parts of the bed. It is evident that a long grate having air admitted only through a narrow door at the front end of the ashpit will not give even distribution of air, neither will the grate which is extremely wide and short with but one door in the center of the ashpit. Provision should be made if the grate is very long for admission of air back near the bridge wall and if the grate is very wide for admission of air at the sides as well as in the center.

Of course, there should be depth enough between the bottom of the ashpit and the grates not only to give plenty of air space but so that the ash and clinker can accumulate for a reasonable length of time in the bottom of the ashpit without causing the grate bars to overheat, as will be the case if the ash bed gets up close to the bars. Extra depth of ashpit can hardly do any harm except that it raises the boiler farther above the floor line; if the grate be hand fired it may raise the grate so far as to make firing more laborious.

The ideal setting involves an ashpit with sloping sides which will throw the ash to the front if it is to be removed by hand, or to a hopper if it is to fall by gravity to a lower level. This sloping side has also the advantage of avoiding dead corners in which the air might possibly eddy around and thus hinder even distribution to the fuel bed. The distance usually adopted from the top of grate to bottom of the ashpit floor runs from 22 in. for boilers 30 in. in diameter up to 28 in. for boilers 70 in. in diameter, these figures applying to fire-tube boilers. For water-tube boilers the same depth may well be used for the same proportionate sizes of boiler. The length of ashpit depends, of course, upon the length of grate and runs ordinarily from 33 in. for a boiler 8 ft. in length up to 63 in. for a boiler 20 ft. in length. For the ordinary 16 and 18-ft. boiler a length of 45 to 51 in. is used, usually the latter. The ashpit door serves, where ash is removed by hand, as a means for taking out the fuel refuse and should, of course, be of size sufficient to allow convenient working.

It is not an uncommon thing to find the ashpit door so small that not only is the operation of ash removal unnecessarily tiresome but the area is not sufficient

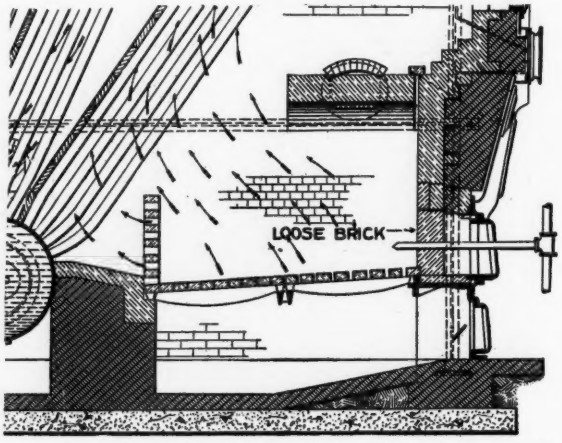


FIG. 2.—THE STIRLING FURNACE FOR OIL BURNING

for the passage of the air required by the fire and either an excessive amount of draft is necessary to pull the air through the ashpit door or the fuel bed goes without sufficient air and a smoky furnace is likely to result.

Grates

Grates are not only to hold the fuel while it burns but must also admit the air for burning at least the fixed combustible and should make the task of the fireman as easy as possible. Small labor cost with a grate involves not only the matter of firing coal onto the grate and of cleaning fires, but also the labor of keeping the grates in proper repair, so that a grate which is unnecessarily complicated or frequently gets out of order may on the whole be quite as much of a trouble-maker as one in which all the breaking up of the fire and slicing have to be done by hand.

In practice it is found that a certain rate of burning of coal usually gives better economy than any other, this point having been discussed somewhat under the heading Requirements for Good Combustion. The amount of fuel which can be burned per square foot of grate depends on the draft, the fuel and the air space in the grate. An extra large amount of air space can do no harm if it is arranged in such a way as to prevent unburned fuel from dropping through the

grate. If the air space through the grate is found to give more air than needed, the draft can be cut down and thus adapt the air supplied to the amount of fuel being burned. If, on the other hand, the air space is too small, it is sometimes a difficult matter to get sufficient draft to pull the required air between the grate bars.

Grate Bars

Evidently the same kind of grate bars will not do for all kinds of fuel. Different styles of bars as adapted for different fuels are shown in Fig. 1. The common bar is, of course, straight, divided into openings and with wedge-shaped cross section of iron to keep the bottoms of the bars cool.

For burning sawdust or slack the bar shown at the bottom of the figure is found to give a greater amount of air space and avoids the packing of the fuel along the bottom of the furnace. For the finest sizes of anthracite, sometimes known as rice coal, flat cast-iron plates, with tapering holes about 0.5-in. in diameter at the upper surface, are frequently used. This gives an air space of some 25 per cent of the grate area. A

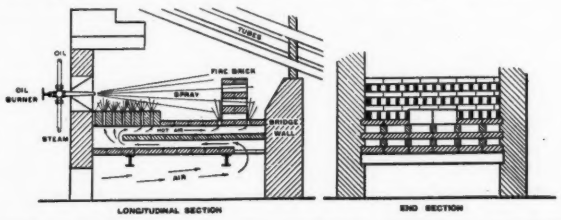


FIG. 3.—FRONT FEED OIL BURNING FURNACE WITHOUT GRATE

larger air space would be desirable, but is difficult to get without allowing the fuel to fall through into the ashpit. Larger sizes of coal are usually burned on grates with rectangular openings, giving from 30 to 50 per cent of air space to the grate.

The herringbone and Tupper grates, which are shown as the second and third from the top in Fig. 1, are stiffer and less likely to warp than the straight bar grates and also give more air space.

As to the setting of grate bars it makes little difference whether these are flat or inclined, except in the convenience of firing. If a grate is long, sufficient inclination to give the fuel a slight tendency to roll towards the back will assist greatly in firing and will have no injurious effect.

The dead plate or solid portion at the front of the grate, which is usually put in for burning bituminous coal, is for holding the green fuel as fired until the most volatile gases are distilled off. After this has occurred the coal is pushed back upon the fuel bed.

Some engineers prefer the alternate system of firing, in which the grate is fed through 2 doors, putting green coal first on one side of the fire and then on the other. If the grate be not too wide, so that the gases from the freshly fired side mingle quite freely with those from the other side, it makes little difference which method is used. If, however, the furnace is very wide so that there is difficulty in getting such mixture, the coking method of firing is the better.

In length the single grate bar should not be over 3 ft. on account of the difficulty of getting a good casting, one which is strong, will not warp and can be easily replaced. Two sections of such bars may be used, making a grate 6 ft. in length. More than this is difficult to fire by hand, but with some stokers and automatic feeders grates have been successfully fired up to 9 ft. and in a few cases rather more than this.

A difficulty which always exists, however, unless a shaking grate is used, is that of cleaning the fire. With bituminous coals this must be done frequently and a 6-ft. furnace is the limit of easy operation. With anthracite coals a furnace up to 12 ft. in length may be used if the firing doors are made large, as the anthracite fire will not require slicing.

When burning very small sizes of anthracite it is necessary to observe certain special precautions. The fuel bed will pack so close that it is necessary to provide mechanical draft, preferably beneath the grate. The fuel bed cannot be carried of great thickness, and the grate area must, therefore, be large. The surface should be perfectly plain to prevent lodgment of coal and should be of such design as to allow ready removal of ash and clinker. Air spaces not over 1/16 to 3/16 in. wide should be provided, if the coal is smaller than No. 1 buckwheat.

Arrangements must be provided for feeding and cleaning fires without opening the doors too frequently,

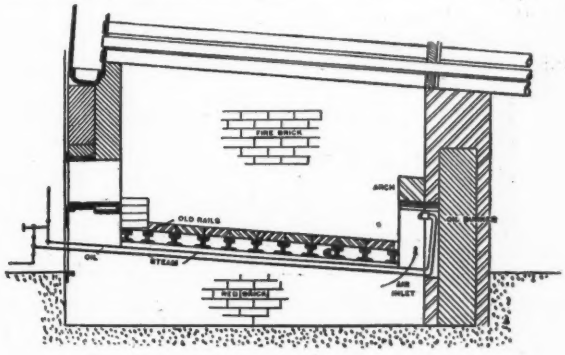


FIG. 4.—PEABODY REAR FEED OIL FURNACE

although the fuel should be fired in small quantities and frequently rather than in large amounts. This involves usually some form of mechanical feeder or spreader. In handling such coal, care is needed to avoid blowing holes in the fire and when the rate of combustion is reduced it should be secured by carrying a thinner fire and reducing the draft rather than by less frequent firing.

All modern experiments tend to show that too large a grate area is quite as injurious to efficiency of the boiler plant as too small grate area. With the grate too small the fire bed is carried thicker than is desirable and it is not possible to get sufficient air through the bed to burn the fixed combustible in the coal properly. On the other hand, with too large a grate area the air supply through the fuel bed is too great and an excess of air is almost sure to result. The effect here is not alone in the combustion of the fuel, but also on the transmission of heat to the boiler. A large surplus of air produces resulting gases of low temperature which do not quickly transmit their heat to the boiler, while if the coal be burned with just sufficient air to give complete combustion, the temperature of the resulting gases will be higher, which will produce a more rapid transmission of heat to the boiler surfaces. A rate of burning of less than 24 lb. per sq. ft. per hour for bituminous coals does not seem desirable. For anthracites a rate of 16 to 20 lb. is probably quite as efficient.

Grates for Oil

It seems absurd to speak of the grate for an oil burning furnace, but this is just as necessary as for the coal burner. The purpose of the grate in the oil burning furnace is, of course, not to carry a bed of

fuel, as there is no bed of fuel to carry, but to hold a firebrick structure which will act as a heat reservoir for the furnace, will mix air thoroughly with the gases from the oil and will supply to the oil spray the necessary air for combustion at a comparatively high temperature. The great problem in burning petroleum or any of its products is to atomize it thoroughly and get it thoroughly mixed with the air.

Grates provided are usually those which would be installed for a hand-fired coal furnace, and on top of these is placed a layer of firebrick; the rear half of the grate being covered solid while the brick on the front half are laid with air spaces from 7/8 in. wide directly under the oil burner tips down to 3/8 in. wide near the middle of the grate. An arrangement recommended by the Stirling boiler designers is that shown in Fig. 2, in which the portions of the grate not directly under the flame are covered with firebrick laid about 1/8 in. apart so that the wide air spaces cover a V shape under the flame. Five-eighths inch air space is left at each side wall to admit a sheet of air which will protect the wall. A perforated firebrick baffle is also erected at the back end of the grate to insure the quick and complete combustion of such gases as strike

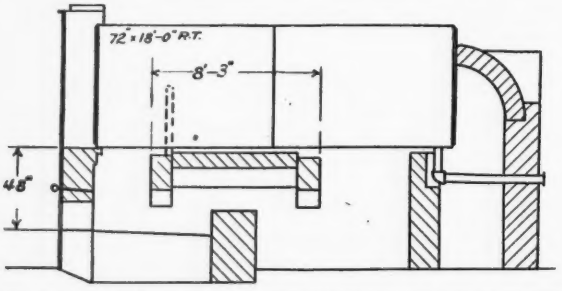


FIG. 5.—A FORM OF BOILER SETTING USED IN CHICAGO FOR BITUMINOUS COAL, WITH GOOD RESULTS

against the lower ends of the first section of tubes. This bridge is usually 14 to 18 in. high and the arch above the grate stops at a point 24 in. from the nearest tube.

If it is certain that occasion will never arise for the handling of solid fuel in a furnace which ordinarily uses liquid fuel, the grates may be omitted and the ashpit filled with ash or refuse firebrick up to a line connecting the top of the bridge wall and the bottom of the ashpit door. The air will then, of course, come through the ashpit door and spread without hindrance directly into the field of the oil flame.

The burner tip for the case shown is placed about 6 in. above the fire brick on the grate and enters either through the fire door or through the brick pier between fire doors. Where the grates are omitted the burner is put through in this same position or on a level with the top of the ashpit doors. The construction of a grate or furnace for burning oil as applied to a 250-hp. Babcock and Wilcox boiler in Chicago is shown in Gebhardt's Steam Power Plant Engineering, as in Fig. 3. This shows the method of front feeding, the same as does Fig. 2, while Fig. 4 shows an arrangement of furnace for rear feeding, a method devised by E. H. Peabody, one of the engineers of the Babcock & Wilcox Co., for use with California oils. The bricks of the partition in front of the bridge wall, Fig. 3, are loosely stacked and can be easily replaced when burned out.

For burning natural gas the same arrangements are usable as shown for burning petroleum. The same fire brick checker work is needed for storage of heat, the same supplementary air supply to provide for complete burning of the gas, the same perforated bridge wall for intimate mixing of gas and air, the only difference being that it is much easier to burn the natural gas efficiently than to burn the petroleum, because it is easier to mix air and gas thoroughly than to mix petroleum vapor and air thoroughly.

Hollow Blast Bars

For burning bagasse, tan bark or sawdust, hollow blast bars are generally used, such as that shown at the bottom of Fig. 1, and these are alternated with plain herringbone or Tupper bars. Sometimes the hollow blast bar is made rectangular with openings on its upper face, these being provided with a sliding plate known as the blast valve, arranged so that the air jets will be nearly in a horizontal direction and crossing each other so that the air supply is under perfect control and will have the widest possible distribution through the fuel bed. Where these bars are used in alternation with the regular bars it provides a furnace which can be advantageously used either on special fuels or on coal, as may be desired. Air is, of course, supplied to these hollow blast bars from a blower or jet system.

The Firebox

For the firebox proper the dimensions must depend upon the fuel and the rate of combustion, and here and in the combustion chamber are the points where there is more chance for skillful design to give good efficiency and avoid smoke than at any other part of the furnace installation. For anthracite furnaces the dimensions of the firebox chamber can run quite uniform, regardless of the source of the coal, since all anthracites have reasonably near to the same characteristics. When, however, it comes to a matter of bituminous coals, the furnace dimensions must vary with the amount of volatile material and the amount of ash as well as with the rate of combustion. For instance, figures frequently given for the depth of the firebox from grate bar to the under side of the horizontal fire tube boiler run from 20 in. for a 30-in. boiler up to 30 in. for a 72-in. boiler. These figures will do reasonably well for the anthracite regions, but when it comes to Ohio, Indiana and Illinois coals or even to those of Western Pennsylvania and West Virginia, no such easy rule can be followed.

Paul P. Bird, superintendent of the Smoke Department of the City of Chicago, in a paper before the Smoke Prevention Convention, gave as figures which the department has found advisable, 42 in. from grate to shell for a 60-in. boiler, 48 in. for a 66-in. boiler, and 51 in. for a 72-in. boiler. It will be noted that the smallest of these is larger than the largest dimension provided for the anthracite fuels, and these figures serve simply as an indication of what we are coming to find out, that generous space for the mixing of air and volatile gases and for the completion of their combustion is absolutely essential to good furnace economy. The length of firebox is, of course, governed by the length of grate.

It is a curious thing that some engineers have advocated in times past the building of a bridge wall which would throw the gases close to the shell of the boiler for a horizontal fire tube setting, which would seem to be an unreasonable performance as it would throw these gases against the chilling surface of the boiler before combustion could possibly be completed.

The method of giving alternate spaces for expansion and contraction of the gases is, however, one of

the methods now recognized as serviceable for producing intimate mixture of the air and volatile hydrocarbons, therefore insuring good combustion. While this method would somewhat chill the gases, it would produce intimate mixture and so long as the temperature was not reduced below that of ignition, the contraction at this point followed by the expansion in the large combustion chamber would make for a complete combustion and in some cases might increase the efficiency of the boiler. The same result can, however, be procured in other ways with still better results.

Plenty of air space through the firing door should be provided to give air supply above the grate.

Figure 5 is one method adopted by the Smoke Prevention Department in Chicago, which consists of a partial arch built of firebrick over the bridge wall. This gives in effect the Dutch oven furnace for a large part of the gases and thus not only allow of an extended period for the completion of combustion but gives also

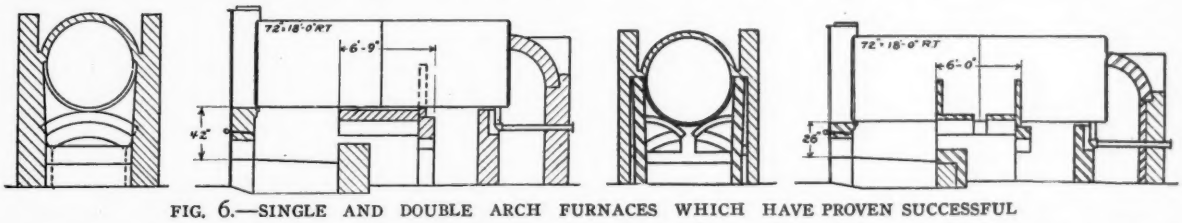


FIG. 6.—SINGLE AND DOUBLE ARCH FURNACES WHICH HAVE PROVEN SUCCESSFUL

the contracting and expanding effect which will result in thorough mixture. A small portion of the gases from the grate will pass between the boiler shell and the brick wall and will afterward mingle with those gases which have passed beneath the arch. If during this first pass any unburned particles of hydrocarbons get through into the combustion chamber they will have a chance to burn there because of the high temperature of the gases in the combustion chamber coming through the lower arch and at the same time the capacity of the boiler is not cut down by this arrangement.

A point made by Mr. Bird in favor of this construction is that the furnace temperature is not kept so high and when the fire door is opened the fireman is not subjected to such intense heat as is the case where a furnace enclosed completely with firebrick is used; also, the brick arch over the entire fire box is difficult to maintain because of the intense heat generated.

Modifications of this construction are shown in Fig. 6. Mr. Bird recommends the installation of steam jets with furnaces of the design of Fig. 6 B; although they are not always necessary, at times they may be needed to prevent the making of smoke. He states that the double arch construction, Fig. 6 B, is the best thing that we know for a tubular boiler set according to old standards. The deflection arch behind the bridge wall is one of the important features of these settings for the reasons already mentioned.

As to stack height, 70 ft. is adopted as the minimum when the stack sets directly on the boiler, and 6 in. must be added for every foot of breeching used, and 10 ft. for every right angle bend in the breeching.

For water tube boilers a fire arch or a tile roof is recommended with a distance of 8 to 10 ft. travel before the gases strike the tubes.

Combustion Chamber

This subject is so intimately connected with the firebox that it is difficult to separate the two. They serve, however, different purposes. The firebox answers for the mixing of the gases and air at high temperature, while the combustion chamber should be of such size and design as to permit the thorough burning or chemical union of the oxygen with the carbon and hydrogen. The arches mentioned under the subject of Firebox Construction constitute an important part of the combustion chamber, but these arches are not it. The chamber should have sufficient space and length to allow the completion of this combustion.

Just the amount of time needed will depend, of course, largely upon the proportions and how intimate the mixture of gases and air has been. The rate of flame propagation through a mixture of gases is, however, 32 ft. a second in mixtures of hydrogen and oxygen, 3⅓ ft. a second in mixtures of carbon monoxide and oxygen. Mixing inert gases with the combustible gases reduces this rate of propagation materially. It is evident, therefore, that the combustion chamber must be of a size to allow the gas to remain in it for a perceptible period in order to insure complete burning before the gases strike the cooler surface of the boiler.

In his discussion of the use of the tile roof furnace, Professor Breckenridge states that the termination of flame which marks the end of combustion came somewhere between the bridge wall and the end of the tile roof. By studying the figures of that setting, it will be seen that this gives a flame length measured from the arch of from 8 ft. 4 in. to 14 ft., depending on the rate of forcing the fire. In some experiments made by the Chicago Smoke Department a baffle wall 11 ft. long was used and found satisfactory, so that it may reasonably be inferred that a distance of 10 to 14 ft. for flame travel before the gases strike the water heating surface of the boiler will be sufficient for any case. In many cases this can be made less.

As to the depth of combustion chamber to be allowed, there seems to be no standard practice in regard to this. It seems a fair assumption that no harm can be done by an extra amount of volume in the combustion chamber, so that a safe rule would be to take all the space that can be secured in the boiler setting and usually with a firebox properly constructed to avoid the production of smoke and secure complete burning of the fuel and gases the space available under the boiler will be all that is needed.

The practice frequently adopted of filling up a part of the space behind the bridge wall with ash would seem to have no basis in reason. The method of a sloping floor has been apparently one of convenience in cleaning out the combustion chamber rather than otherwise.

It should be remembered that maintaining extremely high temperatures in the furnace is hard on the lining and, therefore, where furnaces are built to keep up the temperature and avoid smoke, only the very best of material should be used, otherwise the repair bill is likely to be startling. In any case the cost of repairs with a tile roof furnace or baffle arch, such as shown, will probably be higher than with an ordinary setting.

Bement gives as the cost per boiler per year in a number of plants of which he had charge, $170.48 for the ordinary setting and $250 for the tile roof setting, but the use of the tile roof made a saving in fuel cost of $1,000 a year per boiler, so that the extra $80 was well spent in the extra cost of furnace repairs.

As a rule the inclined arches and those which are curved are less expensive to maintain than the flat arches. This does not, however, apply to flat arches of special strong construction. The flat arch of ordinary construction is likely to need renewing about once a year, while the inclined arch will last about twice as long.

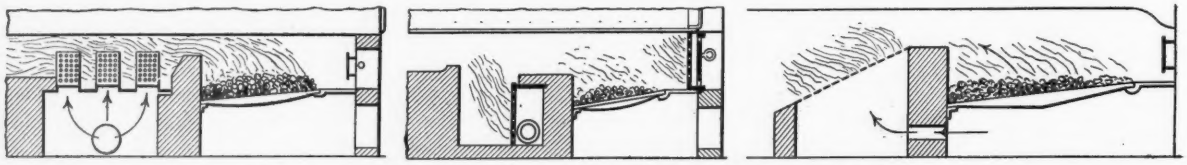


FIG. 7.—PERFORATED BRIDGE WALLS GIVING ARGAND BURNER EFFECT

Bridge Wall

The bridge wall, the dividing line between firebox and combustion chamber, is mainly for the purpose of holding the fuel on the grate but in many constructions it has also been used as a means for supplying air to the volatile gases. Clark gives a number of perforated or argand forms, Fig. 7, the object in all cases being to supply the air at a high temperature and in such location as will compel thorough mixture of air and gases.

BURNING SAWDUST

EXPERIENCE has shown that for the great number of cases a Dutch oven furnace is the best type in which to burn green sawdust. With plenty of space and the furnace kept hot, even sawdust with 30 or 40 per cent of moisture can be burned readily and efficiently. Of course, when the fuel is quite damp large volumes of steam will be generated and it is, therefore, necessary to have a larger space for the expansion of gases than when the fuel is dry. Wedge brick is much better than arch brick for use in constructing these furnaces, as it has the end toward the fire and will, therefore, be more durable. Frequently such furnaces must be used for burning both wood and sawdust. In such case, provision must be made for feed from the front for the wood and feed from the top for the sawdust, a conveyor being the best method for bringing the sawdust to the furnace. This conveyor may well be arranged for a continuous feed, thus giving practically a stoker effect.

FIG. 1. HOLLOW BLAST GRATE BARS FOR SAWDUST FURNACES

In providing grates, large air space should be allowed because the air spaces are likely to fill up and, if plenty of allowance is not made, there will soon be clogging and trouble. With a large air space the amount of draft can be regulated by the damper and the draft doors, so that the air supply will not be excessive while the grates are clean, and the fires can be carried after a considerable degree of clogging up has taken place.

In providing storage for sawdust and calculating the heat value, it may be roughly estimated that 140 cu. ft. of sawdust is the equivalent of 1 cord of wood and is equal to from half a ton to a ton of coal, depending on the wood and amount of moisture. For further data see the subject of Wood under Fuels.

In arranging the grates, the air spaces should be made 0.25 in. wide or ⅜-in. holes should be used, spaced 1.5 in. on centers. There is difference of opinion as to the construction of the combustion chamber for sawdust burning plants. Several writers advocate a long bridge wall which will hold the hot gases close to the boiler surface for a considerable time or even for the whole length of the boiler. A space of 9 in. between bridge wall and boiler shell is also advocated. This does not, however, seem in agreement with what we know as the requirements of good combustion. In a wood fire the fixed combustible is small and the volatile gases large. It would seem, therefore, that plenty of time should be given for burning the gases to get good efficiency. It must, however, be taken into acount that usually where sawdust is used as fuel, efficiency is the least important thing in the plant operation, and forcing the boiler to its highest capacity is of greatest importance. In such cases, keeping the gases close to the shell of the boiler would, of course, increase boiler capacity.

Fire should be carried about 12 in. thick and in the design of the space beyond the bridge wall provision ought to be made for the expansion of gases which must take place during combustion and heating. If this is not done, it means that the gases must travel with ever increasing rapidity over the heating surfaces of the boiler until the temperature is reduced so that the gases begin to contract instead of expand. This will mean a very rapid sweeping of the gases over the heating surfaces and large capacity of the boiler, but will also tend to reduce the efficiency.

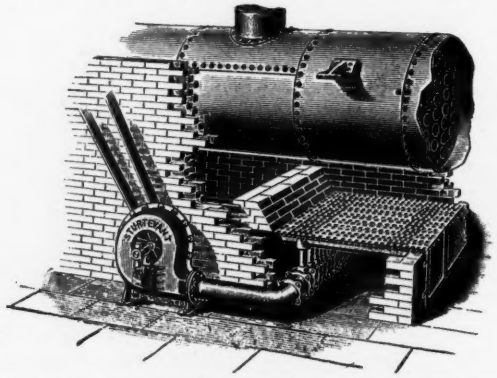


FIG. 2. FAN SYSTEM FOR HOLLOW BLAST GRATES

It should be remembered that sawdust as a rule burns from the top of the fuel heap and from the surface, although on digging into the heap, it may be found that the entire interior is at a high temper-

ature and is rapidly giving off volatile gases. It is better, therefore, to disturb the fire from the bottom as little as possible, as each disturbance of the fuel bed means a loss of fuel into the ashpit. The illustration herewith gives a typical Dutch oven furnace

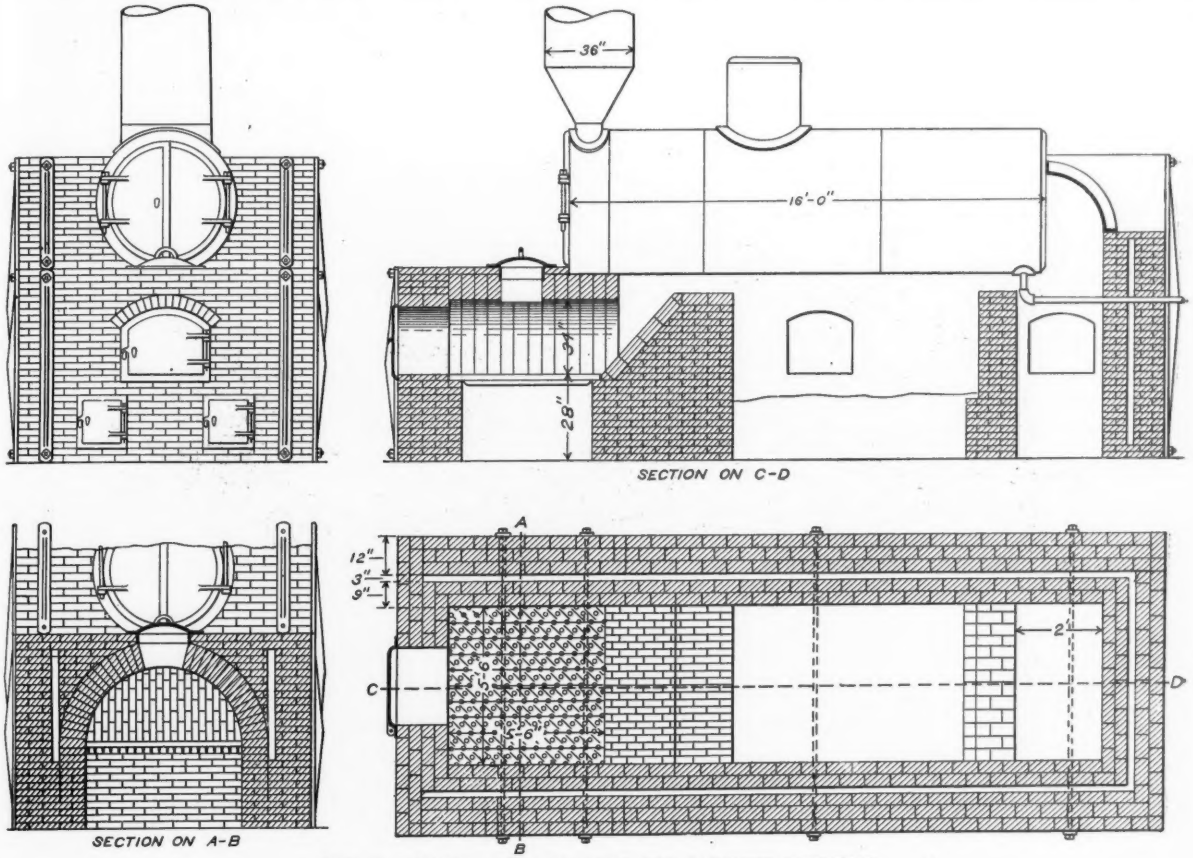


FIG. 3. DUTCH OVEN SETTING FOR SAWDUST BURNING

installation for a wood and sawdust burning boiler with dimensions which have been found satisfactory in practice.

THE GLENMORE ROCKING AND DUMPING GRATE SURFACE

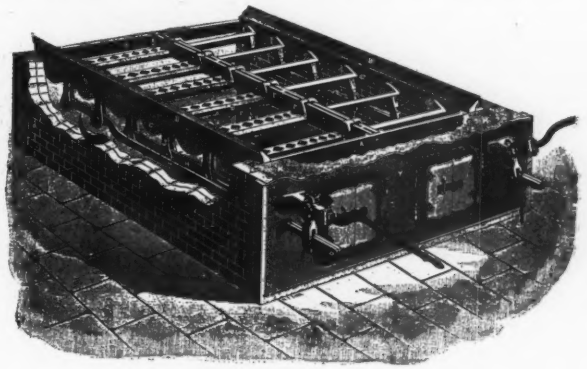
P. J. Conroy, Philadelphia, Pa.

The important features of the Glenmore rocking and dumping grate surface, are its short interchangeable sectional surface bar with extension pin, adapted to an opening in the bearing bar D, when in place forming a mechanically broken surface with air area of 63 per cent.

The bearing bars on and in which the sectional surface bars rest and are firmly supported, are trunnioned at each end and are provided with a socket on the under side in which an independent arm, J, is secured and to which the connecting rod, H, which gives motion to the surface is attached.

The side bars C, extend from the dead plate to the bridge wall parallel with the side walls of the furnace. On them the bearing bars, D, rest and rotate in bearings adapted to them; these side bars rest on and in duffs of the end bars, A. The end bars which support the surface extend from side to side and into the side walls 4 in. or if desired they can be maintained on legs. The middle trunnion bars, E, which are necessary only when the width of the surface exceeds 3 ft. are similar in shape and construction to the side bars, and secured in like manner to the end bars.

When the surface exceeds 4 ft. in depth the leg F is placed and secured between the 2 middle trunnion bars as an additional support. The short interchangeable sectional surface bars, supported by a bearing bar not exposed to the fire and subject to the circulation of the air is a distinct feature. This insures a perfect-



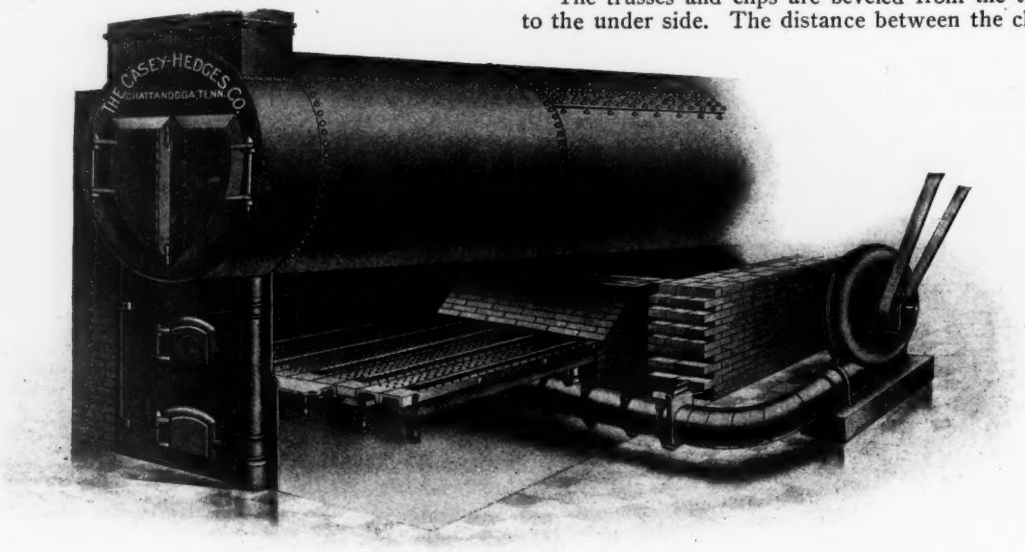
GLENMORE ROCKING GRATE

ly level fire, and the impossibility of warping the surface bars prevents the escape of unconsumed fuel to the ash pit.

The fire can be cleaned without opening the fire or ash pit door thus avoiding a current of cold air entering the boiler and its destructive effects. There is no

need of a poker, hoe, or slice bar as the ash can be shaken out with ease, and the grate kept clean and free from clinker.

The fulcrum and lever arm are so constructed that when shaking the surface a uniform distance is maintained between adjacent sections thus preventing coal from falling through and clinkers from becoming wedged between the lugs which cause unequal strain and consequent liability of breakage.



CASEY HEDGES HOLLOW BLAST GRATE

THE CASEY-HEDGES HOLLOW BLAST GRATES

The Casey-Hedges Co., Chattanooga, Tenn.

The principle of this grate is the same as in the blacksmith's forge. The grates can be attached to any boiler with very little trouble, and are free from complications and cannot get out of repair. The grate consists of hollow grate bars which are provided with holes in the upper surface through which air is forced from a fan blower placed outside the boiler setting. This air is under perfect control and can be varied to suit the needs of the fire.

While this form of grate was designed for burning red cypress sawdust, slabs from oak, gum poplar, cotton wood, and pine, it is also successful in burning low grade coal fuels. One particular advantage of this grate is that it can be cleaned while in operation.

"If you would create for yourself a future—make a present."

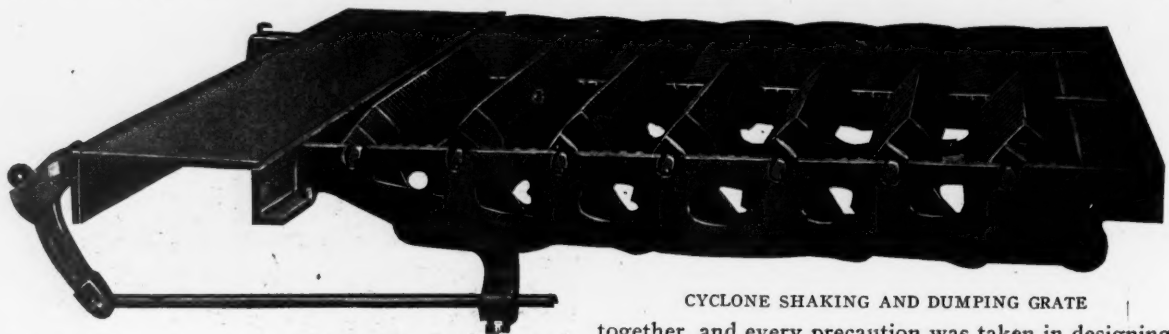
CYCLONE SHAKING AND DUMPING GRATE

Cyclone Grate-Bar Co., Buffalo, N. Y.

The bars of this grate are constructed on the clip and truss plan, having 2 trusses lengthwise, and the clips are bridged across these trusses, each clip forming a double brace with the trusses. This construction gives a uniform strength to the entire bar, without any spots to warp or buckle.

The trusses and clips are beveled from the top side to the under side. The distance between the clips on the surface of the bar for bituminous coal is 3/8 in. and on the under side is 9/16 in. This beveled construction allows all the ash to pass through the face of the bar, and drop directly to the ashpit. It provides also an air passage without friction, until the air has reached the extreme top edge of the opening or face of the bar, thus unbroken currents pass up unobstructed air spaces.

The bars rest in a frame on chilled axles, the frame being constructed without bolts, all parts interlocking together, and every precaution was taken in designing them to prevent warping. Sufficiently heavy material is used to withstand the work required of it.



CYCLONE SHAKING AND DUMPING GRATE

The equalizing bar used in the shaking and dumping device slides on to the trunnions on the arms, which run down from the end of the bars, and are secured by cotter pins, while a wrought iron rod connects the equalizing bar with the shaking and dumping arm on the front of the boiler. This arm locks into a lug which is secured to the front of the boiler by cap screws, and is fitted with a cast steel link which drops into a slot and locks the bars level.

The bars may be shaken as vigorously or gently as may be desirable, according to the condition of the fire, having a motion of 4 in. up and down without opening the spaces between the bars any farther than when the grate is locked level, no unburnt fuel can drop through it. The filing movement of the bars, owing to the fact that they set in the frame eccentrically, cuts the ashes entirely off the bottom of the fire, making it possible to maintain the free circulation of air through the fire.

When it is desirable to dump the residue of the fire, the shaking lever is pressed downward until the bars are thrown to such an angle that the entire contents of the fire box drop through between the openings, which are then about 4 in. wide, into the ashpit. These grates are installed in 1, 2 or 4 sections, according to the size of the firebox.

THE GORDON HOLLOW BLAST GRATE

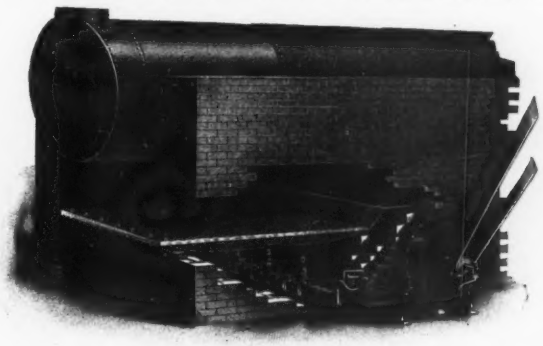
Gordon Hollow Blast Grate Co., Greenville, Mich.

This grate is designed to increase the efficiency of boilers in saw, hoop, stave and heading mills, and to burn wet, green or frozen sawdust, bark, chips and wood refuse generally, which do not burn with sufficient rapidity on a draft grate. The substantial construction of the apparatus, and the fact that the bars are hollow and filled with a current of fresh air, make them practically indestructible.

The apparatus consists of a number of hollow bars, 8 in. wide, separated by special draft bars of the same size, the character of the draft bars being determined by the kind of fuel to be used. In the rear of the ash pit, lying almost against the bridge wall, is a cast-iron pipe. On the bottom of the blast bars and the top of the pipe are nipples into which fit the vertical connecting tubes. The internal shape of these nipples is such that air-tight, universal joints are secured.

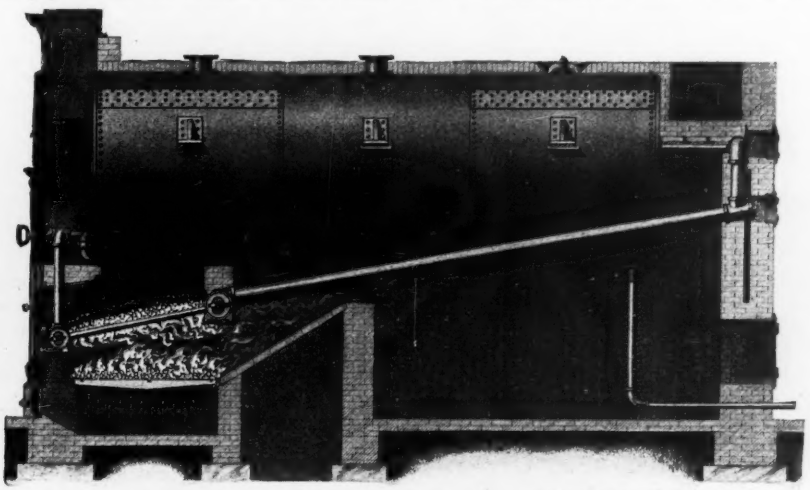
Just outside of the furnace wall, or in any other convenient place, stands a rotary blower, the blast from which is conveyed to the cast pipe by suitable connections of galvanized iron, the pressure and volume of the blast being regulated by a slide, or gate, in the end of the cast pipe, just outside of the furnace wall.

In the top of these blast bars is a series of lids, or tuyeres. The tuyere is a large circular lid containing notches in its circumference through which the blast from the bar escapes into the furnace. Those with the larger or smaller openings can be used, according to the nature of the fuel. Another advantage in having the tuyere removable is that it makes it possible to free the blast outlets from rust or other accumulations. It further gives access to the interior of the bar. It is held in place solely by its own weight, which is 10 lb.



GORDON HOLLOW BLAST GRATE

The tuyere rests on a shoulder, which is at the same time a baffle to prevent the sawdust, ashes, etc., from entering the chamber. There is also a large blowout in the front end of the bar. The upper surface of the tuyeres is slightly below the general level of the grate, so that the scraper passes over them without touching. They are of such shape, too, that it is impossible for them to tilt, or to be taken from their seats unless lifted straight up; so they cannot become accidentally displaced.



RETURN TUBULAR BOILER HAND FIRED. END TO END CIRCULATION.

HAWLEY DOWN DRAFT FURNACE APPLIED TO A TUB

THE HAWLEY DOWN DRAFT FURNACE

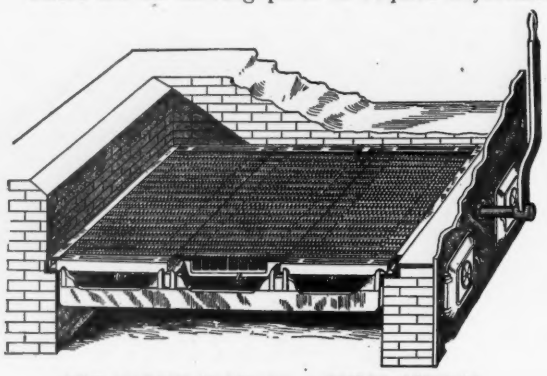
The Hawley Down Draft Furnace Co., Chicago, Ill.

In this furnace the flames travel downward through a water tube grate, placed the same as the ordinary grate, and on which the coal is fired. This grate is piped up with the boiler, and water circulates through it and the piping. A short distance under the water tube grate a second common grate is placed, on which the spent fuel falls as it burns and as the

upper fire is worked. Between these 2, therefore, is a furnace of high temperature in which the fuel, both solid and gaseous, is consumed before passing to the boiler. It will be seen that the conditions for the entire combustion of the coal are thus fully met.

The heat of the gases is made available, thereby saving fuel, while heating surface is added to the boiler and its natural circulation greatly intensified. At the same time, there are no sudden changes of furnace temperature, and expansion and contraction strains, with consequent leakage and repairs, are thereby avoided. The furnace temperatures are practically uniform, as are those of the water in the boiler.

There are no moving parts to require adjustment



THE MARTIN GRATE IN A BOILER SETTING

or replacement, no air or steam blasts to manipulate, and the furnace burns any size or grade of steam coals, without crushing or loss to the ashpile. Ample provision is made for inspecting and cleaning all parts if bad water is used.

The supply pipes take the water from the front end of the boiler and deliver it from the furnace to the hot end, discharging it into the boiler in the direction of the natural circulation, thus augmenting the speed of the water, and making heat transfer more complete at all points. For this reason there is less chance for sediment to lodge and for scale to form.

With boilers of the Heine design the arrangement is much the same as with the horizontal tubular, but the circulating water is taken from the rear water leg of the boiler and delivered into the front, these being the cold and hot ends respectively. In all cases, the water pipes are of ample size and there is always a full supply for the grate.

Each tube of the grate has a removable plug opposite its lower end in the front header, so that it can be inspected occasionally and cleaned if necessary. The circulating pipes also have large plugs, and each drum has a hand hole in one end and a blow-off pipe.

THE MARTIN ANTI-FRICTION ROCKING GRATE

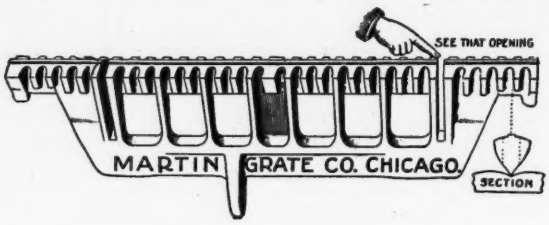
The Martin Grate Co., Chicago, Ill.

Among rocking and shaking grates the Martin seems to embody some rather unusual features which the manufacturers claim have tended to give to the grate long life and efficiency with the cheaper grades of coal.

It goes without saying that there is no opportunity for argument as to the relative merits of the plain, old-fashioned stationary grate bar and the modern shaking grate, which allows the fireman to keep the draft spaces clear all of the time and get resultant better combustion of the fuel.

The manufacturers emphasize the fact that the Martin grate is not a dumping grate, that it is free from wasteful features, and they also call attention particularly to the fact that there are no long fingers to the grate bars which can warp and strike when being brought back to place or which can be left projecting up into the fire to be burned off.

The operation of the grate is such as to abrade and clean the ashes out from the lower part of the fire thoroughly, and because there are no long fingers an extremely thin fire may be maintained on this grate without the danger of breaking through; while there is an abundance of draft area, the individual openings are small enough to prevent the fine unconsumed coal from going into the ash pit. The manufacturers claim that the Martin grate is suita-



A MARTIN GRATE BAR

ble for burning all sizes and grades of coal; that it is especially economical for the cheapest grades, such as slack and screenings, a most important point to the user. It is their claim that with this grate the cheapest grades of coal, such as slack and screenings, will give as much steam as the higher priced coal on common or plain grates.

It is one of the heaviest grates made, weighing approximately 80 lbs. to the square foot of grate surface; is made up to fit accurately each particular furnace for which it is intended, and its installation requires no alteration of the brick work of the furnace, and can be installed easily by the local engineer.

Figure 1 shows an assembled gate and also shows that the grate bars extend lengthwise of the furnace with a perfectly smooth surface, so that cleaning tools may be run over its surface as easily as a common grate. Fig. 2 shows one of the grate bars, which are in very short sections, and the 2 slots cut down near each end at the fire line, which allow for expansion.

It will be noted that the heavier part of the bar is some 5 in. below the fire, with a thorough cross ventilation through it to prevent its becoming hot enough to warp, and the manufacturers state this construction is effective because in their 10 yr. of marketing this grate, they have never had complaint of a warped grate bar.

Each grate bar is supported at either end by a bearing bar on which it rests in the form of an inverted cone, making the grate very easy to operate. All of the frame work of the grate, including the bearing bars, are down below and not affected in any way by the fire, so that the only repairs ever called for are grate bars, which can be dropped into place easily and without the necessity of pulling the fire or shutting down the boiler.

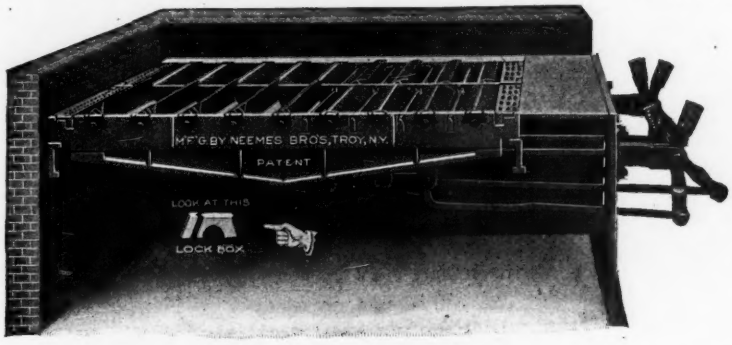
THE NEEMES BROS. IMPROVED GRATE

Neemes Bros., Troy, N. Y.

The shear cutting shaking grate front, and shaking and dumping grate back can be used in combination, as shown in the cut or each grate can be used separately, all through a furnace. Where coal clinkers

much, it is preferable to use this shaking and dumping grate all through a furnace, as with it the use of a slice bar is seldom or never needed. It differs from the shear cutting grate in that it has no shear bars between the shakers. It also cuts the clinker quicker, and with less operations than the shear cutting grate.

With this shaking and dumping grate one can shake out the ashes, cut out the clinker, or dump the fire, if necessary. The shaking grate employs shear bars placed between the shaking bars to aid in the cutting and breaking of the clinkers. The shaking



THE NEEMES IMPROVED GRATE

bars have teeth which are undercut and concave so that when rotated by the shaking lever a pocket is formed, then a shear-cut is made against the shear bar. By this action clinkers and ash are first rolled upward to the shear bars, then cut into small pieces and deposited into the ash pit, thus cleaning the bottom of the fire perfectly and without letting any unburned coal through.

This grate is air spaced to burn any size or kind of fuel and works equally well under all conditions, without clogging or altering the air space. The necessity of opening the fire doors for slicing is eliminated as the shaking and cutting action of the grate cleans the underside of the fire of clinkers and ash. This provision is a fuel saver in that no cold air is allowed to enter over the fire to retard or prevent combustion.

As provision is made for the expansion of the stationary and shaking bars in the side bars and boxes, the grates do not buckle, warp, or get out of shape. These grates can be installed in any shape of water tube or large return tubular boilers, and are made in sizes to fit any boiler, without alteration of brick work.

A special form of lock box is employed into which the grate bars fit, which prevents the shakers from rising into the fire and causing the burning off of the teeth. This is shown in the illustration.

CENTURY ROCKING GRATE

Kewanee Boiler Co., Kewanee, Ill.

Two styles of this shaking grate are made, the essential difference being that one has a center rest and the other has each grate extend entirely across the furnace; the former is recommended for boilers larger than 42 in. in diameter. Each style may be had with 2 different openings, which are adapted for burning run-of-mine coal, slack and screenings. The Century grate is self-contained, and can be attached to any style of setting without changing the brick work of the furnace.

The approximate weight, including rests and all attachments, is 65 lb. per square foot.

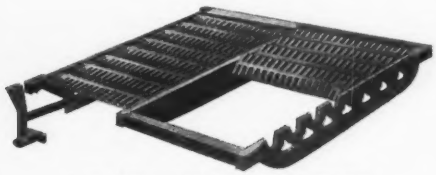
The rocking motion is simple and positive, and well adapted to breaking up caking coal fires without the aid of a slice-bar, and to freeing the grate entirely from ash, thus affording unrestricted air openings.

THE NEW ENGLAND GRATE

The New England Roller Grate Co., Springfield, Mass.

Of several different styles of grates manufactured by this company, the two which seem best adapted for use in power plants are the improved roller grate, and the flat top rocking and dumping grate.

The roller grate is of the shaking type, and is built



THE CENTURY ROCKING GRATE

to handle all kinds of fuel, fine or coarse, without waste. Whether in motion or at rest it is always level, and may be left in any position without risk of burning or injuring any part. There are no dead holes or slots in the surface of the grate, or stationary bars

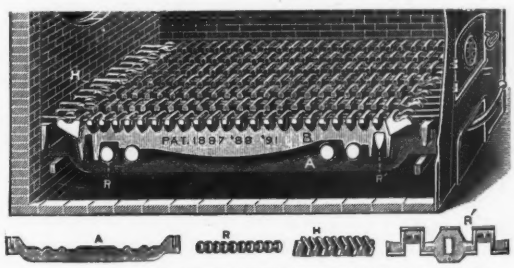


FIG. 1.—THE NEW ENGLAND ROLLER GRATE

at the sides of the fire box, but all air space is alive, and the entire surface is moved at once from the center to the extreme ends and sides of the furnace.

The mechanism upon which the movement depends consists of only 1 piece, it's office being simply

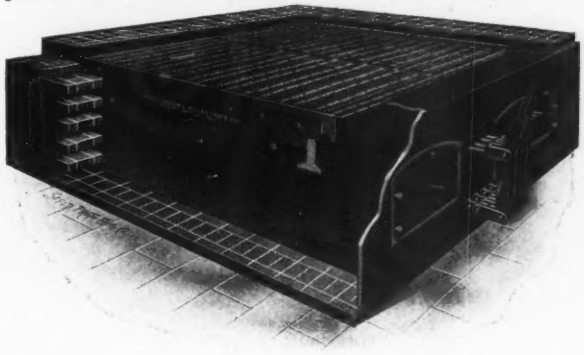


FIG. 2.—NEW ENGLAND FLAT TOP ROCKING AND DUMPING GRATE

to reciprocate the bars, the whole weight of the grate bars and fire being suported by and moved on rollers which does away with friction of iron upon iron.

All parts of the grate are placed and held loosely in position without bolts, screws, nuts or fittings of any kind, the bars being reversible, and all parts interchangeable.

The flat top rocking and dumping grate is made of separate sections of teeth held in position by a special method and maintains the surface of the grate practically level when not in motion.

When the grate is level all cross bars tilt toward the front or ash pit door. In this way the air is given a chance to go up directly through the grate, for burning coal without checking it. The whole grate is self-contained, consisting of but 3 parts, to be renewed in case of repairs, which may be done at slight expense. By changing the teeth the grate can be adapted for the use of any size fuel.

The grate can be so arranged that one-half or one-quarter can be shaken or dumped without interfering with the rest of the fire. It is adaptable to any boiler, without changing the fire box, and is furnished with any desired air space.

THE PERFECTION SHAKING AND CHOPPING GRATE

Perfection Grate Co., Springfield, Mass.

When at rest an absolutely flat surface is obtained on this grate for bedding, no ribs or projections interfering with the slice bar or other tools. When in operation the projecting and interlocking points are forced up into the bed of clinker and ash, breaking it up in staggered lines, and rocking both ways, agitate every inch of fuel bed, allowing no opportunity for large clinkers to form and freeze fast to the grate bars. As the clinker and ash are stirred up with each successive upward tilt of the rockers, this clinker and ash slides down into the opening of the bars and is there held until the return movement, when it is crushed through into the ash pit, thus preventing the sudden fall of coal along with the ash which often takes place when using straight edge grate.

From 25 to 55 per cent of air space is provided in these grates and is evenly distributed and remains constant at all times. The different grades of air space

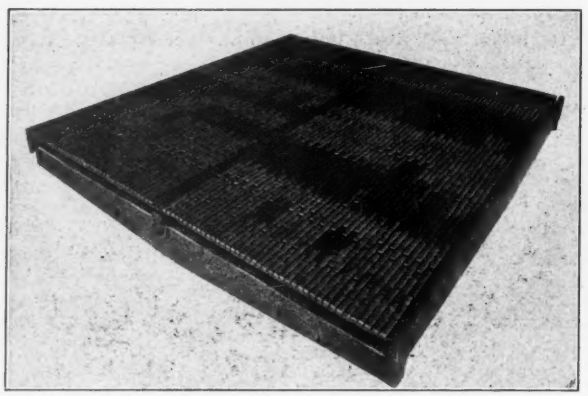


FIG. 1.—THE PERFECTION GRATE WITH SURFACE FLAT

are obtained by using different styles of teeth. The surface of each grate being made up of small detachable and interchangeable tops or teeth, which may be changed to suit the grade of fuel to be used.

The curve on the under side of the teeth is such that any foreign substance which cannot be crushed into the ash pit may be pushed gradually back on the surface of the grate, thus preventing the grate from becoming stuck in an improper position. The grate proper is free from brick work and supported on small iron brackets bricked into the side walls of rectangular fireboxes, and rests upon regular rings or lugs of upright boilers.

For shaking the grate the handle is provided which stands well away from the boiler front and is so constructed that it cannot be removed from its socket without leaving the surface absolutely level.

REAGAN IMPROVED CHOPPING GRATE

Reagan Grate Bar Co., Philadelphia, Pa.

A novel yet effective method of stoking a boiler furnace fire is by means of the Reagan device shown in the illustration. It consists of a series of stoker

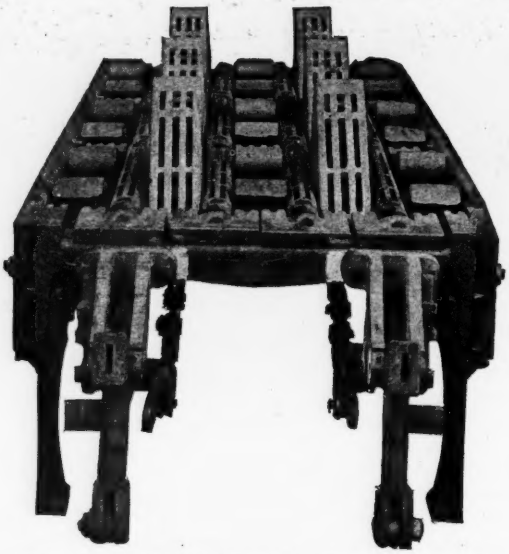


FIG. 1.—REAGAN IMPROVED CHOPPING GRATE

castings, 3 in series, extending the entire length of the grate. The number of series in the width of the grate is determined by the size of the furnace.

The entire grate is made up of interchangeable units fitted together as they come from the foundry, and with no bolts exposed to the fire. The grate bars

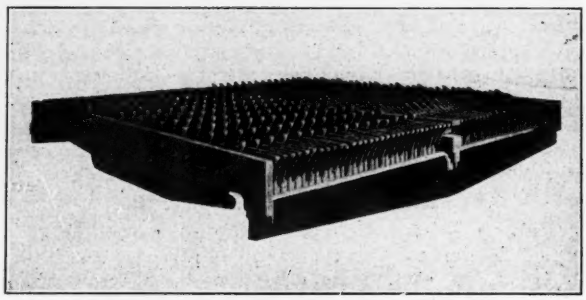


FIG. 2.—PERFECTION GRATE IN DUMPING POSITION

in detail are shown in the accompanying illustration, and the method of their operation by the 2 levers at the front of the grate will readily be understood.

BLACK SMOKE IN THE EXHAUST from a gas engine comes from too much fuel; blue smoke from too much oil.

THE MANSFIELD BALL BEARING GRATE

Wm. E. Rider & Co., Mansfield, Mass.

This is a shaking grate that is designed to handle all kinds of fuel, fine or coarse, without waste. It is always level whether in motion or at rest, and may be left in any position without risk of burning or injuring any part.

There are no dead holes or slots in the surface of the grate, or stationary bars at the sides of fire box, all air space is alive and the entire surface is moved at once.

The mechanism upon which the movement depends consists of only 1 piece, upon which there is no weight, its office being simply to reciprocate the bars, the whole weight of grate bars and fire being supported by and moved on non-fillable self cleaning ball bearings, hence the movement is positive and easy, there being no friction of iron sliding on iron.

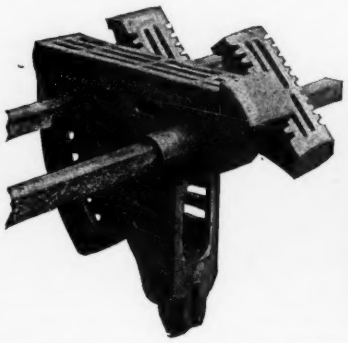
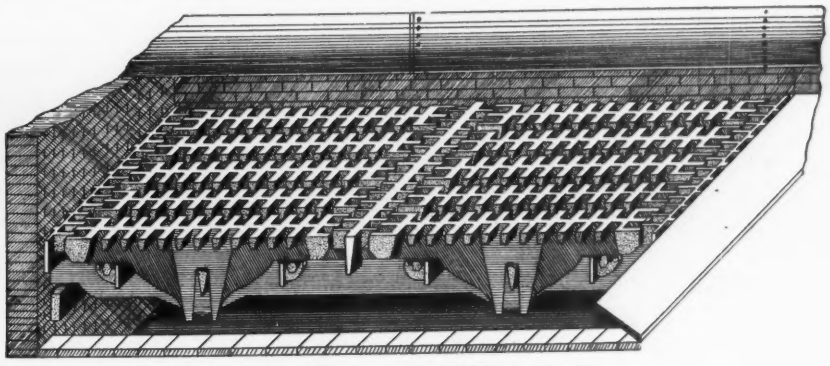


FIG. 2.—DETAIL OF REAGAN GRATE



MANSFIELD BALL BEARING GRATE

All parts of this grate are placed and held loosely in position, the bars being reversible, and all parts interchangeable. Air space to the amount of 65 per cent can be developed. Model No. 1 has grate bars that extend the entire length of the furnace. These are made preferably for small fire boxes, not to exceed 5.5 ft. in length, and are usually installed so that at least 2 sections are operated separately.

Model No. 2 is designed for those who wish short grate bars beneath their boilers. This is advantageous for it increases the cleaning ability by allowing the back section to be operated separately without disturbing the front or vice versa. The cost of grate bar repairs is thus reduced and there is less tendency for grate bars to warp. These are made with either the flat or corrugated top, and are always level whether in motion or at rest, and at no time is any part tipped over and exposed to the fire.

When at rest they present the same level appearance as the ordinary grate. A drop is cast on the front rocker to which the shaking attachments are connected as shown in the illustration. A lever put into the socket in the swinging bracket and worked up and down gives the grate a vertical and horizontal movement. By this action, the under surface of the fire is thoroughly cleaned and opened, a condition which can be obtained with 1 or 2 moves of the lever which is operated easily with one hand.

The construction of the Aetna grate is simple and such that the grate can be put in any furnace on the ordinary bearing bars without change or delay. The combustion obtained by the use of these grates is good, as the air space is over 60 per cent. The shaking of the grate dispenses with the use of a slice bar, and reduces the friction to a minimum. Cleaning the fires without opening the door and exposing the boiler to injurious drafts of cold air saves the boiler from strains due to temperature changes.

Rogers grate which is shown in Fig. 2 has a peculiar construction to prevent warping and twisting which is one of the most prevalent troubles with boiler grates. The grate has a large amount of air space about evenly distributed, giving complete combustion and insuring long life.

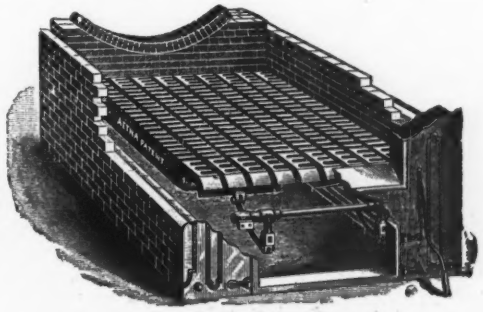


FIG. 1.—THE AETNA SHAKING GRATE

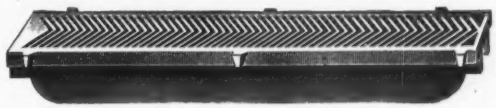


FIG. 2.—ROGERS SECTIONAL GRATE

A commendable feature in the construction is a ventilating air space between the outer sides of the longitudinal supporting ribs and the circumscribing band or ties connecting the lateral ribs or the V's. The longitudinal supporting ribs are underneath the

BOILER FURNACE GRATES

Salamander Grate Bar Co., New York, N. Y.

Of several styles of grate bars made by this company, the two that seem best adapted for power plant work are the Aetna shaking grate, and the Rogers sectional grate.

In Fig. 1 is illustrated the Aetna shaking grate, showing the improved shaking attachment, and the manner in which these grates are put in the boiler setting. Upon the ordinary bearing bars, are laid according to the width of furnace 2 or more stationary bars; suspended between these openings at either end are placed the 2 rockers, which swing freely, like a scale bearing upon pivot edges; upon these rockers are placed the moving bars.

web, and set in from its outer edges, making the whole series of supporting ribs equidistant from each other, thus allowing a free circulation of air between them and keeping them cool, which prolongs the life of the grate.

With different air spaces, the grate is adapted for burning equally well all kinds of fuel, from lump or broken coal to pea screenings, soft coal, tan bark, wood, and other kinds of cheap and waste fuel.

HALL GRATE BAR

Stowell Mfg. & Foundry Co., South Milwaukee, Wis.

In order that a furnace employing a stationary grate bar may give complete combustion some special construction must be resorted to. The Hall grate bar is of a peculiar design, with air ports which allow free and unlimited ventilation, resulting in hot fires and cool bars.

The webs are placed below the fire surface, thus being removed from the direct action of the fire, and consequently out of danger of becoming overheated.

HALL GRATE BAR

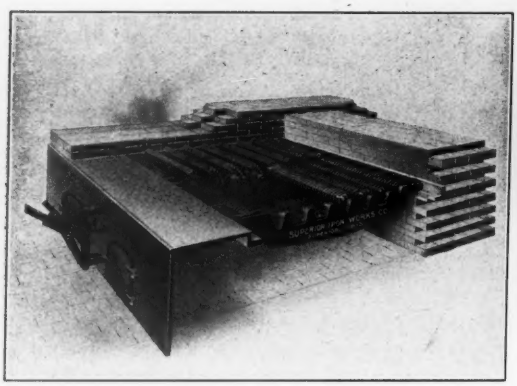
These webs are attached to a single, deep backbone, in such a manner that no unequal expansion and contraction can result.

The fire surface of the grate is level, so that a long T shaped poker pushed flat along under the fire on the bars will sift the ashes through the grate and keep live coals in contact, thus insuring a clean fire and good draft.

SUPERIOR SHAKING AND DUMPING GRATE

Superior Iron Works Co., Superior, Wis.

This grate is built along simple, strong, durable lines to secure economical combustion at a moderate price. It will be noted from the illustration that the construction of the supporting bars brings the body of the bar well below the fire, and that the lower edge is ribbed, thus preventing undue expansion of the bar and warping. The trunnions are sufficiently below the surface of the grate to allow projecting end fingers on the ends of the grates, which makes the total surface area a part of the shaking grate surface. This location of the trunnion causes a longitudinal motion of the grate surface from front to back of the furnace when being shaken, thus causing a cutting action of the grates and thoroughly cleaning the under side of the fire.



SUPERIOR SHAKING AND DUMPING GRATE

The trunnion pins are cast on the supporting bars, and fit in cored holes in the grate ends, one end being an open slot to drop over the trunnion pin; the grate is held from lifting by a cotter pin below the trunnion. The center rib of each individual grate is depressed below the surface of the grate, and thus adds 17 per cent to the actual air surface of the grates, as compared with grates having the center bar flush with the surface. To clean the fire a slight movement of the shaker bar is sufficient, and this does not enlarge the space between the grates enough to waste coal, while the full motion throws the grate into the dumping position.

The furnace is divided into 2 side sections, and each side may be divided into front and back sections if desired. The fires can thus be cleaned in full or in part without opening the fire doors.

Any grade of coal can be burned on these grates with economy and their efficient action, large total air space, and general makeup which prevent distortion and lead to long life are commendable features.

WILLOUGHBY SHAKING GRATES AND FURNACES

A. B. Willoughby, Philadelphia, Pa

These grates can be used in all kinds of furnaces, and all kinds of fuel can be burned upon them. They are especially adapted for internally fired corrugated furnaces, where either natural, forced or induced draft is employed.

The furnace which is of special construction is simple and so designed that no cold air is admitted over the fire. Either hard or soft coal may be used in these furnaces, and they reduce the clinker to a minimum. The grates are designed with ample air space and are easily operated by a shaker wrench. In the construction of the grate there are no bolts, nuts or cotter pins to become loose or broken, which reduces the liability of a disabled grate to a minimum.

THE WILLOUGHBY GRATE FOR INTERNALLY FIRED BOILER

The grates running longitudinally present a flat surface to fire upon, while a slice bar or hoe may be used without catching in the openings.

OIL BURNING

IN the eastern market oils are so high in price and coals so low that it is seldom that oil is to be considered as a power plant fuel. For the most part, oils from states east of the Mississippi River are available for illuminating and lubricating purposes and industrial uses; they are easily refined so that they are too valuable to be used in large quantities for power work. In the southwest, however, the Texas and California oils, which are of low grade and low cost are frequently used. Native coals in that section are of poor quality and imported coals are of high cost because of transportation charges. Frequently the crude oil must be treated to remove sulphur, earthy matter or water before it can be used in the boiler furnace. When so treated it is usually termed on the market "fuel oil."

Advantages that oil has aside from the considerations of price are that a barrel of oil containing 42 gal. and weighing from 310 to 332 lb. will occupy about 50 per cent less space than an equal heat value of coal and will weigh 35 per cent less. Boiler efficiency will also usually run higher with oil fuel than with coal on account of the completeness of combustion secured in an oil burning furnace and the ease of regulating the air and fuel supply. With coal a boiler efficiency of 70 per cent is high, while with liquid fuel 75 per cent is not uncommon and 80 per cent has been frequently attained.

Conditions for good combustion in an oil burning furnace have already been discussed and the arrangement of oil burning plants is the point left to consider. Provision should be made for supplying plenty of air, but it is usually better to cut down the air supply to the point where faint smoke just begins to appear, as an excess of air is more common than a lack.

Methods of Burning

Two methods of burning oil are in use, one by burners of the injector type, in which steam or compressed air is mingled with the fuel oil inside the burner and thrown into the furnace as a spray; the other, in which the oil drops upon a sheet of steam or compressed air as it leaves the nozzle and is, therefore, mixed with the steam outside the burner. The injector type is the more common in present day practice.

As between steam and compressed air for an injecting medium, air will undoubtedly be more efficient from a heat standpoint, but requires more expensive apparatus and provision for heating it to get the best results. Steam, on the other hand, comes to the burner with a minimum of controlling apparatus and serves as its own heat conveying medium and also to heat the oil, a condition which is necessary to get the best results.

Oil Temperature and Pressure

The oil should be carried into the burner at a temperature of about 150 deg. and the pressure for the steam supply is from 60 to 120 lb. for the high-pressure systems and 15 to 40 lb. for the low-pressure systems. Each system has its earnest advocates. Low draft is usually advisable, for 0.02 to 0.15 in. of water, and a flue gas temperature of 430 to 500 deg. F. being found desirable in operating conditions.

Storage and Feeding

Storage of the oil and supply to the burners is an important feature of an oil burning plant. Frequently the storage tanks are buried underground, but this means that they are difficult to get at for repairs and a wiser plan is to install them in a pit but mounted on brick piers so that they can be gotten at for painting and repairs at any time and will be kept dry. Sometimes steam coils are put into the tanks to heat the oil; usually, however, the oil is heated as it comes to the burners. A pump system is used to draw the oil from the tanks and force it to the burners. The gravity system is all right for feeding oil from tanks so far as the operation of the burners is concerned, but involves a certain element of danger from too rapid a flow of oil or from the blowing out of the flame when the burners are running low, allowing a large amount of explosive mixture of air and oil vapor to collect in the furnace.

In the best plants the oil is supplied under a constant head, frequently with a stand pipe, as shown in the illustration, to regulate the pressure. The pump draws oil from the storage tank and forces it through the pressure regulator to the burner, an overflow being provided to return any excess oil from the regulator to

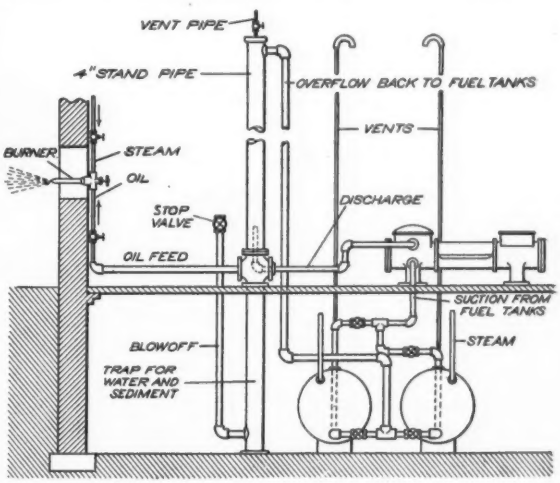


FIG. I.—ARRANGEMENT FOR STORAGE AND PUMPING OF OIL.

the reservoir. A trap is also provided for taking out any dirt or water which may be carried to the regulator with the oil.

The gravity head or pressure head under which the oil comes to the burners may be anything from 5 to 30 lb., different operators advocating different pressures. In any case it is important that the pressure on both oil and steam should be uniform, as otherwise the furnace would operate at widely varying capacity, causing unsteady operation of the boiler. The less steam or air that can be used, the better, so long as combustion is complete.

As in any other boiler plant, the use of the gas analysis apparatus and pyrometer in the flue will help materially in securing efficient operation.

Burners

Selection of an oil burner is an important factor. The burner must, of course, depend upon the oil. Texas oils are thinner than those from California, the California oil weighing about 8 lb. per gal., while the Texas oil weighs 7.4 lb. to the gallon. Right here it should be noted that, in buying oil, contracts should be made by weight rather than bulk, as the number of heat units in a cubic foot of oil varies widely with the temperature of the oil, while the heat units per pound for a given grade of oil are nearly constant.

With Texas oil a temperature of 130 deg. F. is usually sufficient, while California oil should run to

180 deg. or over. With thinner oil a pressure of 35 lb. steam and 30 lb. on the oil has been found satisfactory

In another Texas plant at Galveston the air pressure is carried at 15 lb. and the average consumption is 2.47 lb. of oil per kilowatt-hour. In a plant at San Antonio, which uses a flat, flaring nozzle, giving a spreading flame, the steam pressure is 90 lb. and the oil pressure 45 lb., the average consumption being something less than 4 lb. per kilowatt-hour. At El Paso the chief engineer, C. L. Forsyth, uses steam at 155 lb. and oil at 120 lb. after having experimented with a wide range of pressures. He provides for uniform regulation of steam and oil by a Mason regulator

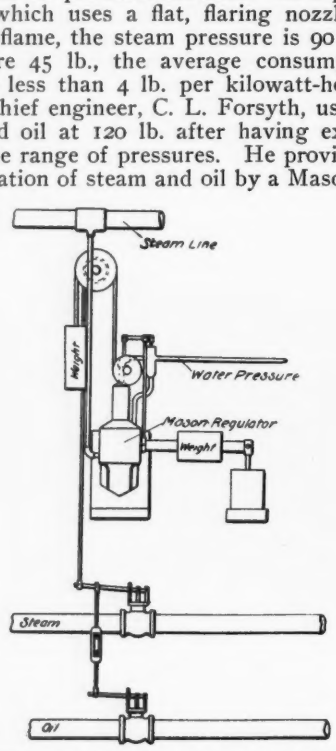


FIG 2.—SYSTEM FOR CONTROL OF OIL AND STEAM SUPPLY AUTOMATICALLY WITH A MASON REGULATOR

and a couple of balanced valves, one of which controls steam and the other oil, the arrangement being as indicated in Fig. 2.

Conclusions reached by the United States Naval Fuel Board as a result of a long series of tests are that air for combustion should be heated before entering the furnace, oil should be heated, as it atomizes more readily, when using steam, high pressures are better than low for atomizing the oil, and that for forcing boilers compressed air will be found more advantageous than steam because the air will assist in the combustion, while the steam will simply take up space needed for the air supply in the furnace.

THE SPRINGFIELD ADJUSTABLE FUEL OIL BURNER

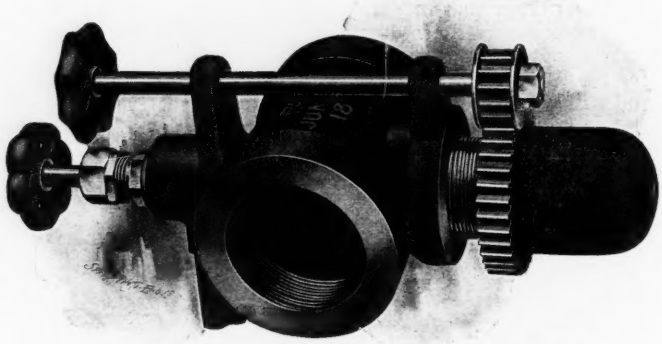
Gilbert & Barker Manufacturing Co., Springfield, Mass.

Full velocity of air is maintained at the tip of this burner regardless of the volume used, by means of an adjustable nozzle. This arrangement causes so perfect and complete atomization of the oil that it burns completely in the furnace and with the most economical results. The oil is so perfectly broken up by the air that the resultant flame is similar to a gas fire, as dry, clean and smokeless in every particular as a natural gas or coal gas flame.

In the method used to apply the burners to the furnace, the compressor is required to furnish only the air to atomize the oil, free air being drawn in around the burner sufficient for complete combustion and no more. In this way the oil is burned with a minimum amount of air and the most economical results obtained.

Air is delivered by means of a compressor to the burner under a pressure of 1.5 lb. and upwards to the square inch, which on account of the peculiar construction of the burner is sufficient to atomize the oil. An oil pump is belted to and driven by the compressor and should the compressor stop the flow of oil must stop also, preventing the possibility of pumping unatomized oil into a furnace, a feature of safety heartily appreciated by operators.

The storage tank is buried at a convenient distance outside the building on a lower level than the burner. The oil pump delivers the oil from the storage tank directly into the oil distributing pipe, and any



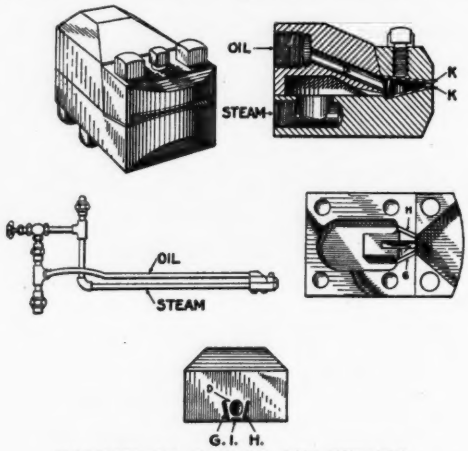
THE SPRINGFIELD ADJUSTABLE FUEL OIL BURNER

surplus through a relief valve back into the storage tank. By this means a constant supply of oil under uniform pressure is provided.

HAMMEL OIL BURNERS AND FURNACES

Hammel Oil Burner Co., Los Angeles, Cal.

This oil burner is of the inside mixer type which permits the steam and oil to come into contact, and the oil is atomized inside of the burner itself, and the mixture issues from the burner tip all ready for combustion at once. It is designed so that it will handle



HAMMEL OIL BURNER AND DETAILS

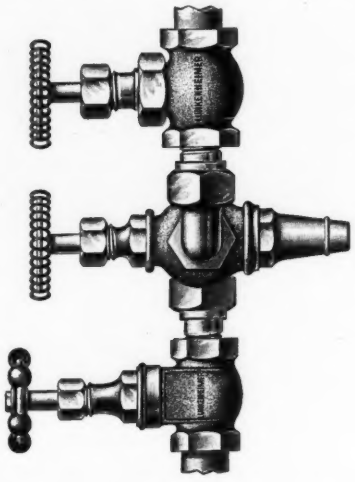
hydrocarbon fuels of any gravity without using more than a small fraction of the steam generated by the boiler, without necessitating preheating of the oil, and yet permitting quick and cheap renewal of parts affected by wear or erosion due to gritty oil.

Referring to the illustration it will be seen that oil enters and flows through D into the mixing and atomizing chamber; steam enters as indicated, passes through 3 small slots, G, H and I, into the mixing chamber C, where it meets the oil, and as these small steam jets cut across the oil stream at an angle the heavy hydrocarbons are completely atomized, the light hydrocarbons are vaporized, and the completed mixture issues from the burner and ignites like a gas flame. The passages of this burner are sufficiently large so that they will handle coal tar with the same success as they do oil, and many of them are used for this class of work.

LUKENHEIMER OIL BURNERS

The Lukenheimer Company, Cincinnati, Ohio.

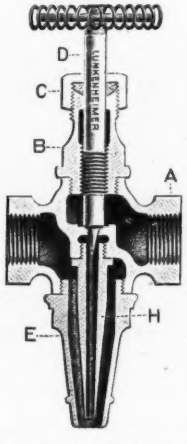
Passages through this oil burner are free and unobstructed, thus preventing any possibility of the oil



LUNKENHEIMER OIL BURNER

clogging up the passages and interfering with the proper flow.

Referring to the sectional view herewith, it will be



SECTIONAL VIEW OF LUNKENHEIMER OIL BURNER

seen that the valve D is designed with a needle point, thereby permitting a very fine regulation of the flow of oil. Such parts subjected to wear, particularly E and H, can readily be renewed.

ROCKWELL FUEL OIL PUMPING SYSTEM

W. S. Rockwell Company, New York, N. Y.

In this system the crude oil for fuel is pumped from storage tanks to the burners, and at the same time heated with the exhaust steam. This system

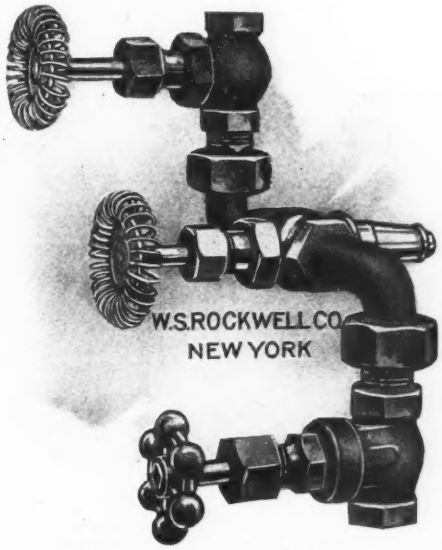


FIG. 1.—ROCKWELL OIL BURNER

forces the oil to the burners under a suitable uniform pressure, and the best possible condition for rapid and complete combustion. It handles equally well light or heavy oil, automatically supplying 1 or 100 burners with equal pressure and perfect safety, as no

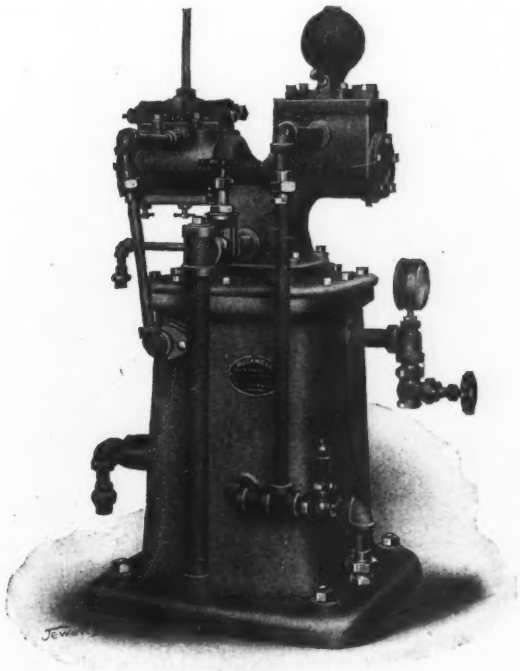


FIG. 2.—ROCKWELL OIL PUMP

oil is above the level of the burner, and the system is in no way governed by the gravity of the liquid.

The storage tank is placed outside of the building, thus keeping all but the smallest possible quantity of

oil outside. There is no oil visible at any time from the storage tank to the fires, and the system is perfectly clean without leakage or odor. The operation is entirely automatic from the start, and perfectly simple to understand and operate.

The accompanying illustration may be taken as a fair illustration of the necessary appliances and the method of delivering and burning fuel oil under boilers. Different conditions of location will, of course, necessitate different arrangement of appliances, but the principle of delivery, storage and pumping should remain as shown herewith as far as possible.

The storage tank should be so placed as to admit of the oil being discharged from the tank car by gravity. If the storage tank cannot be located wholly below the ground level, its top should, if possible, not extend above the level of the burners. The best location for the pumping system is in the pump room, engine room or other convenient location, not in the boiler room, and the oil delivery pipe carried from it along the front of the boilers, with a branch to each boiler. All oil lines should be laid below the ground if possible, but if not they should be well secured and protected.

The pump used in this system for delivering the oil from the storage tank is steam actuated, the exhaust steam being used for heating the oil. Where the nature of the work is such that it is desirable to have a duplicate pumping plant, 2 complete machines mounted side by side and connected to the suction and delivery line are furnished; these machines operate independently, one kept in reserve for emergency.

The Rockwell oil burner is employed in connection with this system. For operation it requires dry steam at boiler pressure and ordinary chimney draft, same as with coal.

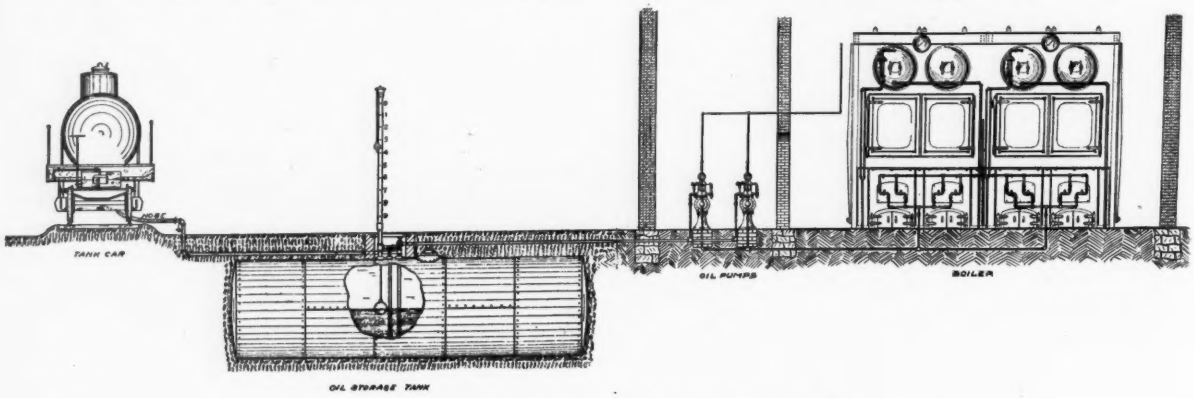


FIG. 3.—ARRANGEMENT OF OIL PUMPING SYSTEM

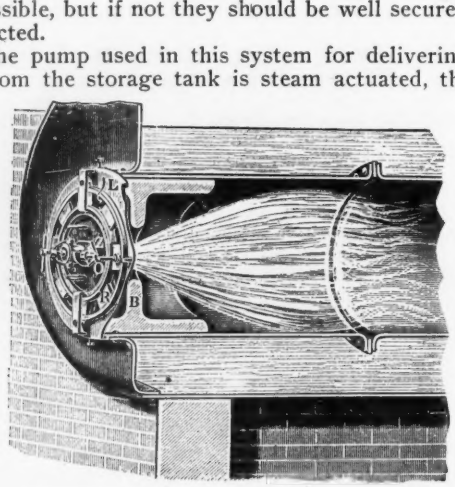


FIG. 1.—KOERTING OIL FIRING TYPE A-1 OIL FIRING SYSTEM

KOERTING OIL FIRING SYSTEM.

Schutte & Koerting Co., Philadelphia, Pa.

Two methods of oil firing are employed by the Schutte & Koerting Co., in spraying petroleum, raw naphtha, mazut, astatki, etc.: One, type 1-A for marine and stationary boilers and locomotives, in which the oil is heated above the boiling or flash point before being sprayed, of which a full description follows. The other uses steam directly as the atomizing medium, and is described as type 2-A.

In the type 1-A system the oil flows from a supply tank to a central pumping outfit, where it passes through a primary heater and flows through filters to a pressure pump. The pump passes it under a pressure of from 50 to 75 lb. and presses it through a second header to the centrifugal spray nozzles directly in front of the boiler.

In the second heater it is heated to 260 to 300 deg. F., i. e., the oil is heated above its boiling or flash point at atmospheric pressure. Evaporation of the oil in the first stage is prevented by the pressure on the pumps being kept in accordance with the temperature. The moment, however, the oil leaves the nozzles under the boiler, pressure is removed and it flashes into a spray. This physical action is assisted by the mechanical atomizing of the spray nozzles, resulting in the perfect and intimate mixture with the air. This gives the desired results of a smokeless and perfect combustion.

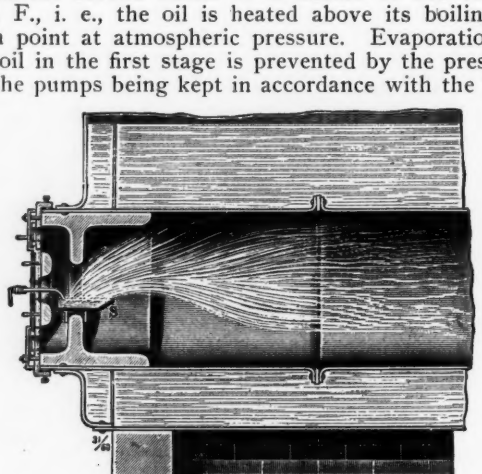


FIG. 3.—KOERTING OIL BURNER FOR HEAVY OILS

The second system employed by this company pro-

vides a low cost for installation in small plants where the fuel is of thick and tarry nature, and gives reliable service. The disintegration of the fuel into fine drops is effected by means of a jet of steam, a mixture of air jet and steam, or air jet. The bare steam-jet should be employed for spraying heavy fuel like tar. For light fluids, a mixed jet, steam and air, or air only, can be used.

The tar is lifted to a tank on top of the boiler by means of a steam-jet exhauster and flows from the tank to the boiler by gravity. The oil should be heated in a tank if possible at about 150 deg. F. The regulation of fuel or oil is accomplished by means of cocks. No special heaters or strainers are required.

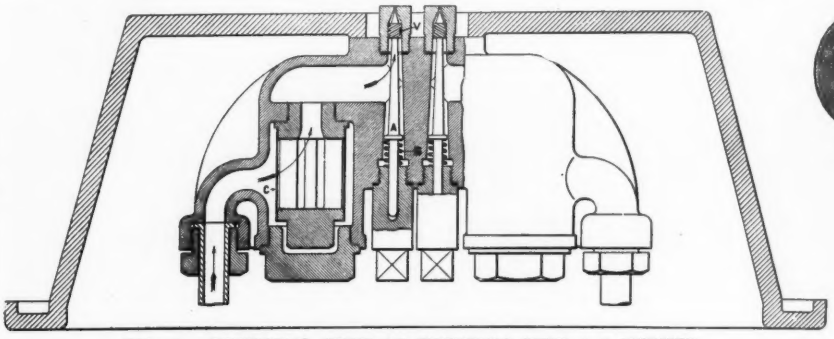


FIG. 2.—SECTIONAL VIEW OF KOERTING TYPE A-I BURNER

KIRKWOOD OIL AND GAS BURNERS

Tate, Jones & Co., Pittsburg, Pa.

In the sectional view of the No. 1 Kirkwood oil burner, which is shown here, it will be seen that both the oil and the steam valve feed at the tip of the burner, the pressure being thus maintained at the point of exit of the oil and steam. This arrangement does away with the dead steam, which results when the supply is reduced by a valve which throttles the steam further back.

As the oil passes through the burner it is heated by the steam, surrounding the oil pipe, which is used to atomize the oil. Emerging from the tip of the burner, in an almost imperceptible spray, the oil is instantly ignited and complete combustion takes place. Both the oil and the steam valves on the burner are equipped with indexes, by which the fireman may see exactly the amount of oil and steam turned on, and maintain a much better regulation than would be possible otherwise.

The No. 4 Kirkwood burner has 1 lever to control both the steam and oil supply. The proportion is fixed at the factory and the ratio always remains at the constant point which is found to be the proper proportion for complete atomization; adjustment being made before the burner leaves the factory insures a burner, the efficiency of which cannot easily be impaired. The burners are introduced through the ash pit opening, the burner proper being at the front of the boiler within easy access, the atomized oil traveling back under the grate bars and issuing from the nozzle located in the bridge wall and projected toward the front of the boiler, insuring the utilization of the complete heating surface of the boiler. The air for combustion is drawn through the ash pit door and is heated in its passage under the grates.

The Kirkwood natural gas burner consists of a nozzle and an outer and inner casing, forming a circular space into which a large number of small pipes, having small holes or jets, are introduced. The gas is introduced into this circular space through an opening provided for that purpose, and from there into the small pipe, and comes out into the body of the burner through the openings in a large number of fine jets, and mixes with the air which is drawn through the burner.

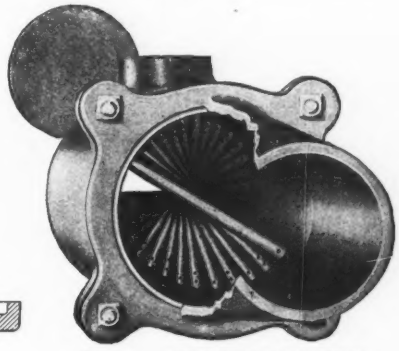


FIG. 3.—KIRKWOOD NATURAL GAS BURNER

The Kirkwood gas burner is also made with small brass spuds instead of the pipes extending across the inner casing, leaving a larger space for air draft but at the same time insuring by means of the spuds a complete breaking up and mixture of the gas and air. With this type of burner natural gas can be used successfully at a pressure as low as 0.5 ounce.

FIG. 1.—KIRKWOOD OIL BURNER

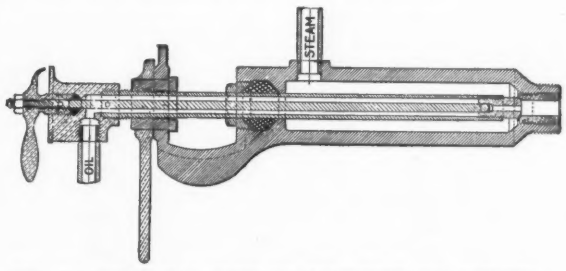


FIG. 2.—SECTIONAL VIEW OF KIRKWOOD OIL BURNER

The degree of economy in burning natural gas lies, to a great extent, in how completely the gas and air are mixed, and this burner is so constructed that the correct mixture of air and oil is obtained. The spiral arrangement of the pipes breaks up the air and introduces the gas into it with a swirling motion, which effects a thorough and complete mixture in proper proportions.

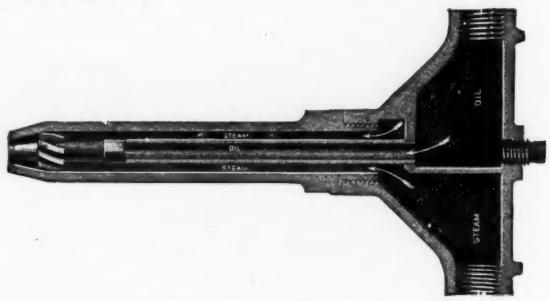
With from 2 to 8 ounces gas pressure each burner will work effectively, evaporating the equivalent of 25 boiler horsepower at 2 ounce gas pressure, and with a pressure of 6 to 8 ounces the equivalent of 35 hp. is developed.

On account of variation in steam draft and gas pressure an air damper is placed on the back of each burner for regulating and keeping constant the amount of air admitted to the burner.

THE GEM BURNER

The Petroleum Iron Works Co., Sharon, Pa.

In the illustration herewith of the Gem oil burner, is shown clearly the construction of the apparatus. The oil entering at the top under pressure passes through a tube, surrounded by an annular ring of steam under pressure which heats the oil to a high degree before it passes through the nozzle at the end of the burner. Steam entering at the bottom of the burner passes through the annular ring surrounding the oil pipe, and through a series of baffles placed near the end of the burner, which give it a twirling motion, and this together with the contracting of the pipe at the end of the nozzle thoroughly atomizes the oil to be burned.



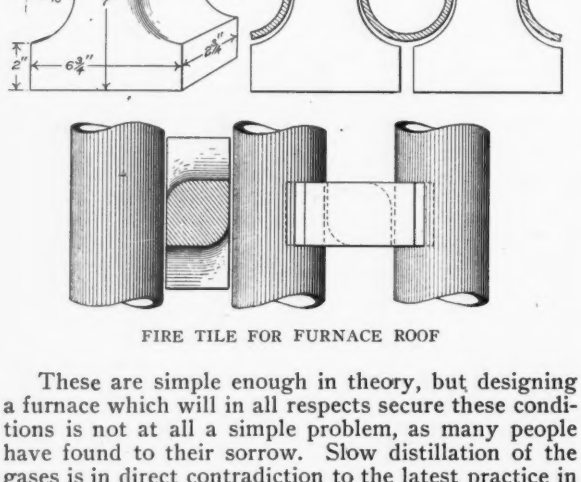
THE GEM OIL BURNER

A plugged hole is provided at the bottom of the oil chamber for cleaning out the burner.

REQUIREMENTS FOR GOOD COMBUSTION

TO AVOID CO AND SMOKE

THESE have been well stated by a number of authors and experimenters, and a combined summary of these statements may be made as follows. The gases must be distilled from the coal slowly and uniformly; these gases must be brought into intimate contact with heated air and enter a fire brick chamber which is either of such length as to allow the flames to complete combustion entirely, or is provided with such auxiliary baffling and mixing devices as to cause the air and gases to be mixed and combined before they leave the chamber; while burning, the gases must not come in contact with any cold surface which will reduce the temperature.



FIRE TILE FOR FURNACE ROOF

These are simple enough in theory, but designing a furnace which will in all respects secure these conditions is not at all a simple problem, as many people have found to their sorrow. Slow distillation of the gases is in direct contradiction to the latest practice in boiler operation, which tends towards operating at twice or three times the capacity heretofore thought desirable. Uniform distillation is not consistent with varying load. A long combustion chamber in modern crowded quarters is difficult to arrange. Spite of all these drawbacks, it is entirely possible to provide furnaces which will not cause smoke.

Use of Fire Brick Arch

Professor L. B. Breckenridge states that it is now the opinion held by most engineers that the boiler has very little to do with the making of smoke, except that some types of boilers lend themselves better to a good furnace construction than others. He considers that it is necessary, however, to pay special attention to the coking arch under which fresh fuel is fired. When a special furnace apart from the boiler setting is possible, the problem is simple; when this cannot be had, it is necessary to adopt some device like a tile roof furnace that gives an arch under the boiler itself. The length of arch that is necessary before the gases strike the cool tube surface depends upon the volume of volatile products distilled in a given time, so that a coal high in volatile, or a boiler planned for a high rate of combustion, call for a long arch, and vice-versa.

Coals with volatile up to 40 per cent have been burned and the rate of combustion run as high as 40 lb. per sq. ft. of grate but this involves not only careful design, but careful handling if the furnace is to be run without forming smoke.

Use of Baffles and Piers

Putting in baffles in furnaces may not always be helpful unless it is done with understanding, for it may so reduce the draft available as to make it impossible to get enough air through the fire to burn the coal needed to keep up the capacity of the boiler. Of the tile roof furnaces, those which have a flat roof seem on the whole to give the best results.

It is safer to install a tile roof of sufficient length to be sure of avoiding smoke than to resort to baffles and piers to mix the gases but this device takes up room and is likely to reduce the heating surface of the boiler materially. In the case of the fire tube boiler, the tile roof is likely to be impracticable, and resort is necessary to some form of Dutch oven or to mixing baffles or jets of air above the fire. The twin arch brick furnace which keeps the gases away from the boiler plates altogether is an effective preventive of smoke, but involves some sacrifice of heating surface.

Sure Smoke Producers

Conditions sure to produce smoke are to install a fire tube boiler with the usual furnace which is too

small for using bituminous coal, and then fire this by hand in not too careful a fashion with run of mine coal.

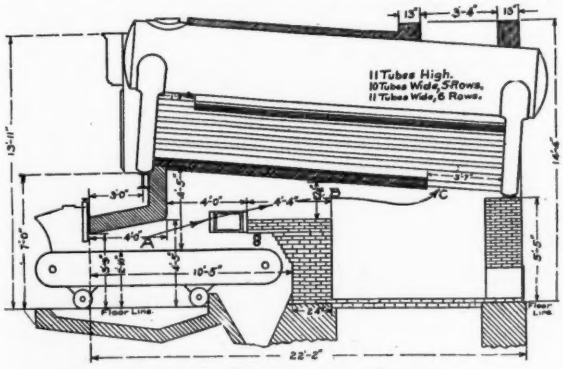
Fire Room Rules

Regardless of the type of furnace used, it is necessary to have good work on the part of the firemen, and for securing this a set of rules has been compiled by the Illinois Coal Operators' Association, which are full of helpful suggestions. They are given in full:

Rules for Firemen Using Illinois and Indiana Coal in Hand Fired Furnaces

1. Break all lumps and do not throw any in furnace larger than one's fist. The reason for this is, that large lumps do not ignite promptly, and their presence also causes holes to form in the fire, which allow the passage of too much air.

2. Keep the ash pits bright at all times. If they become dark it is evidence that the fire is getting dirty



BRECKENRIDGE'S "SMOKE PROOF" FURNACE

and needs cleaning, which if not done will cause imperfect combustion and smoke. If the furnace is equipped with a shaking grate, it should be operated often enough to prevent an accumulation of ash in the fire. Do not allow ash to collect in the ash pits, as it not only shuts off the air supply, but may cause the grate to be burned.

3. In firing, do not land the coal all in one heap, but spread it over as wide a space as possible as it leaves the shovel. A little practice will enable one to catch the proper motion to give the shovel to make the coal spread properly.

4. Place the fresh coal from the bridge wall forward to the dead plate, and do not add more than 3 or 4 shovels at a charge. If this amount makes smoke, it should be reduced till smoke ceases, which means, of course, that firing be at more frequent intervals than formerly to keep up steam. This rule applies in cases where the boiler is worked at a large capacity. In such instances, however, where a small capacity only is required, firing by the coking method is the best, wherein the fresh coal is placed at the front of the fire and pushed back and leveled when it has become coked.

5. Fire one side of the furnace at a time, so that the other side containing a bright fire will ignite the volatile gases from the fresh charge.

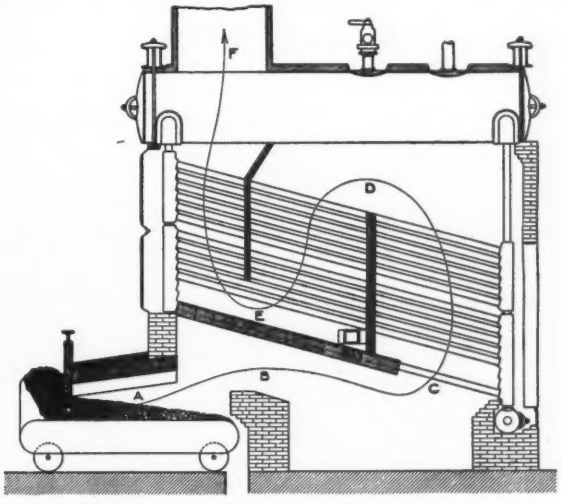
6. Do not allow the fire to burn down dull before charging. If this is done, it will not only result in a smoky chimney, but an irregular steam pressure.

7. Do not allow holes to form in the fire. Should one form, fill it by leveling and not by a scoop full of coal. Keep the fire even and level at all times. As far as possible, level the fire after the coal has become coked.

8. Carry as thick a fire as the draft will allow, but in deciding on the proper thickness, judgment must be exercised. If the draft is poor, a thin fire will be in order, but if strong, a thicker fire should be carried.

9. Regulate the draft by the bottom or ash pit doors and not by the stack dampers, because when the stack damper is used it tends to produce a smoky chimney, as it reduces the draft, while the closing of the ash pit door diminishes the capacity to burn coal. If strict attention is given to firing, according to demands for steam, there will be no occasion to have recourse to dampers, except when there is a sudden interruption in the amount of steam being used.

10. A good general rule is to fire little and often, according to steam demands, rather than heavy and seldom. The former means economy in fuel and a



COKING FURNACE FOR CHAIN GRATES

clean chimney, while the latter signifies extravagance in fuel and a smoky chimney.

Rate of Combustion

It is the first job of a furnace to burn enough fuel to keep the boiler making steam, and this requires grate area and draft; also the grate must be provided with air space enough to allow air needed for combustion to pass. The air will vary with the kind of fuel, as will also the draft needed, and the values as given in the table show the best modern practice.

Kind of Fuel.	Draft Needed. Ins. of Water.	Width of Bar. Ins.	Width of Air Space Ins.
Straw	0.20	⅛	¼
Wood	0.30	〃	〃
Sawdust	0.35	〃	〃
Peat, light	0.4	〃	〃
Peat, heavy	0.5	〃	〃
Sawdust and Small Coal	0.6	〃	〃
Lump	0.4-0.7	½	¾
Egg		〃	〃
Nut	0.5-0 8	⅜	½
Pea		〃	〃
Run of Mine	0.6-0.9	〃	〃
Slack		〃	〃
Slack, small	0.7-1.1	⅛	¼
Dust	0.8-1.1	〃	〃
Semi-Anthracite	0.9-1.2	〃	〃
Breeze and Slack	1.0-1.3	〃	〃
Breeze and Dust	1.2-1.5	〃	〃
Anthracite Slack	1.3-1.8	〃	〃

Twenty to 30 lb. of coal per square foot of grate per hour is good for bituminous coals, and provision should be made for driving the boiler to at least a horsepower for each 5 sq. ft. of heating surface.

Allowable Draft

This should be accomplished with a draft of not over 0.5 in. of water as a higher rate tends to pull holes in the fire. Excessive draft also means the formation of clinker, rapid accumulation of ash, as the grate area will be too small, and the frequent cleaning of fires with consequent loss of fuel and cooling down of the boiler. On the other hand, a grate much too large for the boiler will result in carrying a thin fire which will let too much air through and permit holes to form in the fire easily.

Ratio of Grate Area to Horsepower Capacity and Heating Surface

For eastern bituminous and semibituminous coals with a heat value of 13,000 B. t. u. per lb., taking an overload of 50 per cent, 9 lb. of water evaporated per pound of coal, and 30 lb. of coal burned per sq. ft. of grate per hour. T. J. F. Maguire gives the grate area as 19 per cent of the rated boiler horsepower; the ratio of heating surface to grate surface would then be 52 to 1. This works out to about 19 lb. of coal per square foot of grate an hour at rated load.

For coals having a heat value of 13,500, the evaporation per pound of coal would be 9.5 lb. of water, and for overload of 5 per cent and 30 lb. of coal per hour per foot of grate, the grate is 18 per cent of the rated horsepower, and the heating surface is 55 times the grate surface.

Western bituminous coals with a heat value of 12,000 B. t. u. and an evaporation of 7.1 lb., and burning 35 lb. of coal will take a grate area 21 per cent of the rated capacity of the boiler, and will carry a ratio of heating surface to grate of 48 to 1. For 11,200 B. t. u., the evaporation is 6.2 lb., and with the same rate of combustion, the grate is 24 per cent of the rated capacity, and is 1/42 the heating surface.

Anthracite buckwheat No. 3 having a heat value of 11,000 B. t. u. will evaporate 6.6 lb. of water per pound of coal, 22 lb. of the coal will be burned per square foot of grate; the grate area will be 36 per cent of the rated capacity of the boiler and the heating surface 28 times the grate. For No. 2 buckwheat, with a heat value of 12,000 B. t. u., the evaporation will be 7.6 lb. of water, the grate 31 per cent of the rated capacity, and 1/32 of the heating surface.

THE CLIMAX SMOKE PREVENTER

The Climax Smoke Preventer Co., Boston, Mass.

Variation in coal, careless firing and imperfectly designed furnaces, clearly indicate the need of an automatic device for varying the supply of air furnished the furnace in order to produce more perfect combustion and prevent smoke. The Climax smoke preventer has been designed for the purpose of obviating these difficulties.

This device is based on the steam jet principle, but great care has been taken in the mechanical design and the steam and air supply worked out on a scientific basis. The apparatus is put in operation by opening either fire door and is automatically shut off after the green coal has become incandescent. The valve used has special thread cut on the stem, so that a half turn opens the valve full. The valve stem has a pin through the lower part and is operated by means of a collar fastened to a rod.

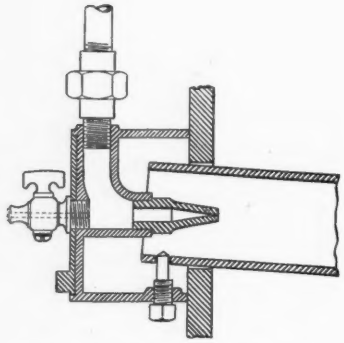


FIG. 1.—CLIMAX STEAM JET

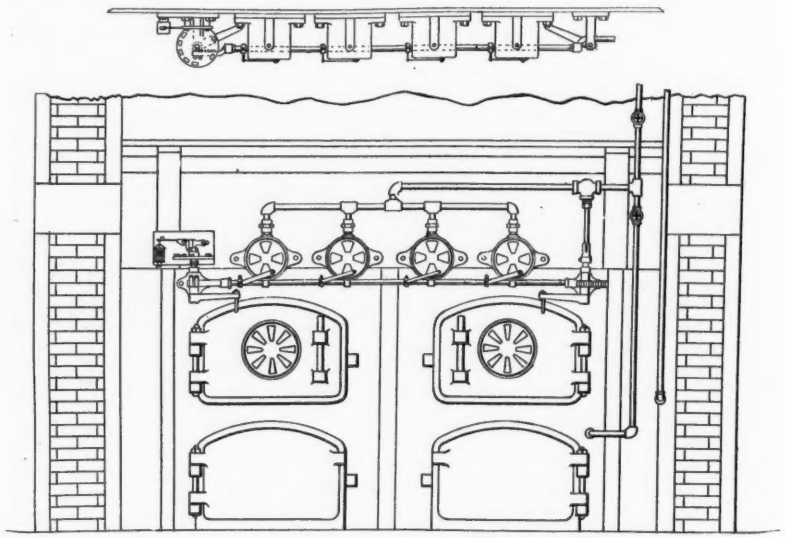


FIG. 2.—CLIMAX SYSTEM APPLIED TO BOILER

The arm by which the motion is transmitted from the fire door to the mechanism is about 6 in. long, 1 end is connected to the shaft, and in the other end is fastened a piece of rod bent at right angles with a roller which rests against the fire door.

The dampers are operated by means of a round rod to which are attached the 2 racks, or slide gear, and collar and pin for each damper. This rod engages a strap that is fastened to the damper by means of a screw. The part of the automatic closing device on the boiler front consists of a standard, on which is mounted a pawl, locking device, solenoid coil and switch, also a special rack with teeth cast on the upper side to engage the pawl. On the shaft is located a compression spring, which when released closes the valve and air dampers.

The timing arrangement which operates the mechanism is controlled by a clock movement, by means of which the time the apparatus is operating after each opening of the door can be regulated to give best results.

An automatic closing device, which operates by water pressure is frequently employed in place of the electric device.

The chief want of life is somebody who shall make us do the best we can.—Emerson.

FURNACES FOR BABCOCK & WILCOX BOILERS

The Babcock & Wilcox Co., New York

Much has been accomplished by the Babcock & Wilcox Co. in perfecting furnaces for various grades of fuel. A number of forms of furnaces have been tried out and are still being tried out, as it is the policy of the Company to make experiments in any line where it appears that something superior to what they are offering may be developed. The arrangements shown in the figures have been used so much that they may be considered standard, but it must be assumed that these are the only furnaces recommended, as many other forms are used.

The Webster furnace shown in Fig. 1 is used mainly for anthracite coal and for mixtures of anthracite and bituminous coals. It is especially adapted to burning the finer sizes of anthracite where a relatively large grate surface is desirable. Narrow combustion arches are sometimes placed over the fire to increase the temperature, the products of combustion passing upward and around the arches before entering the spaces between the boiler tubes. A dumping or shaking grate is used and no difficulty is experienced in

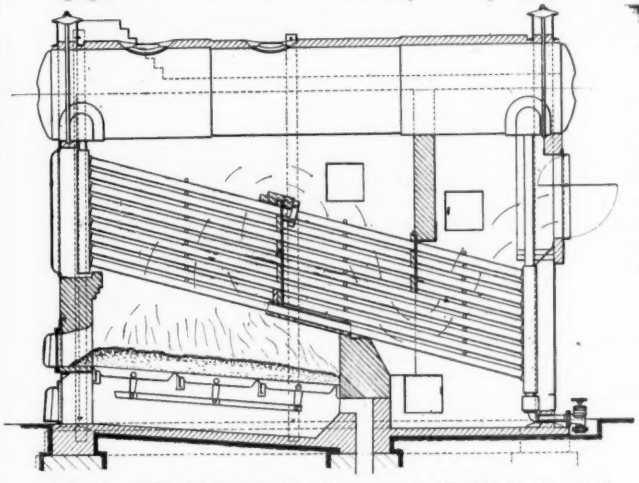


FIG. 1 THE WEBSTER FURNACE FOR ANTHRACITE COAL

handling the fires when the depth of the grate is made as much as 12 ft. By the use of a large grate area and a forced blast sudden demands for steam can be readily met, which is a most important advantage in power plant work, in fact, a boiler which is running at less than its rating can be forced to over 175 per cent of its rating in less than 10 min.

The chain grate stoker shown in Fig. 2 is a type which is employed with great success in burning volatile or bituminous coals. The coal is fed on the front of the grate through a hopper, and ignited by heat radiated from an ignition arch. The ash is discharged at the back of the grate beneath a wrought steel water cooled box connected into the boiler circulation so that no heat is wasted. Although especially suitable for coals which contain over 30 per cent of volatile matter, the advantages of this stoker in minimizing smoke, its reliability of action and small cost of maintenance have created a field for it in the burning of less volatile coals.

The Peabody furnace shown in Fig. 3 is the best type for burning fuel oil. In developing this furnace exhaustive experiments, occupying the time of an expert for about 2 yr., were made which showed that to secure an efficient furnace for oil burning it is necessary to place the burners at the lower side of the combustion space, and discharge the oil toward the larger end of the furnace chamber. The increasing volume of the combustion space in the direction of the flame ensures free expansion and thorough mixture of the oil and air, with consequent complete combustion. This furnace was used in connection with Babcock & Wilcox boilers in the tests of the Pacific Light & Power Co.'s plant at Redondo, California, where a record

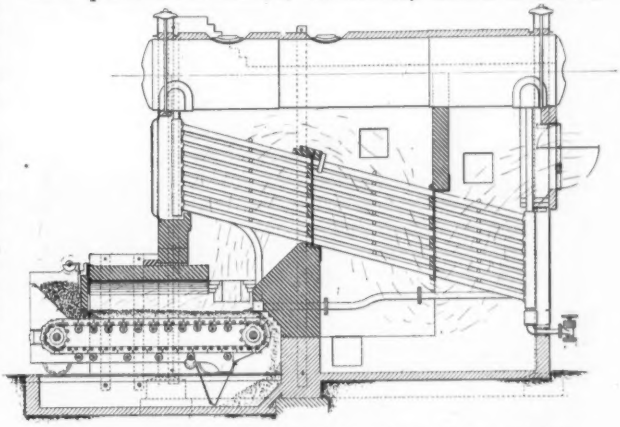


FIG. 2. BABCOCK AND WILCOX CHAIN GRATE STOKER

plant efficiency of about 25,000 B. t. u. per kilowatt-hour was obtained, this figure including the heat of combustion of the oil used for all purposes about the plant, and during a layover period of 4.5 hr. a day. In training the operators for this test, one of the boilers was experimented with, and demonstrated that it was an easy matter, with a trained fireman, to obtain an efficiency of 83 per cent.

Many other forms of furnaces are used besides those shown in the figures. In the case of chain grate stokers 2 forms of setting are employed that are now the subject of patent applications, where the gases are given a longer pass beneath brick work than shown in Fig. 2, and where the cross passes are retained in

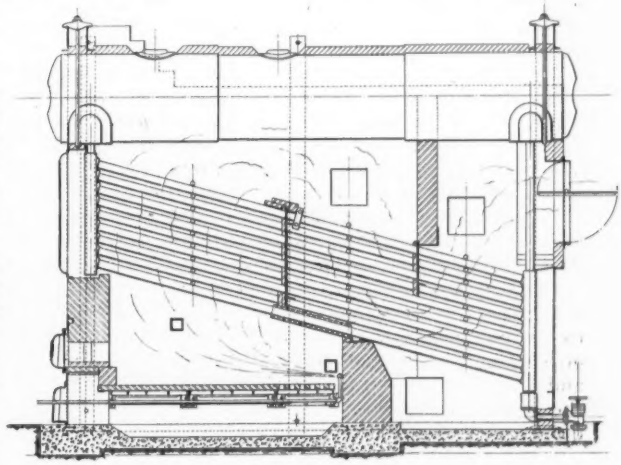
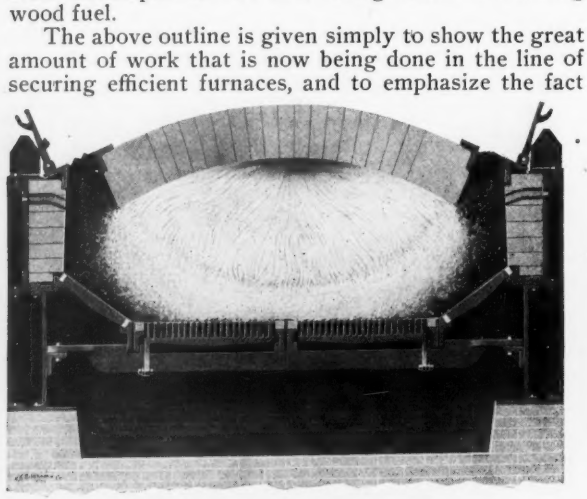


FIG. 3. PEABODY OIL FURNACE

the boiler so that the efficiency of transmission of the heat from the hot gases to the boiler tubes is a maximum. Furnaces for hand firing volatile coals have also received much attention, and special forms have been employed where efficiencies of over 70 per cent can be secured with coals that ordinarily give much less than this even when burned under combustion arches. Care-

ful experiments have also been made in burning blast furnace gases, and a form of furnace developed which gives most satisfactory results. In these tests a special experimental setting was devised where the gases were made to travel a long distance before striking the heating surface, the effect on the combustion carefully studied by means of complete analyses, and the horsepower developed by a given volume of gases compared to that developed with a standard form of furnace. New developments are also being made in burning wood fuel.

The above outline is given simply to show the great amount of work that is now being done in the line of securing efficient furnaces, and to emphasize the fact



BURKE SELF-FEEDING SMOKELESS FURNACE

that to obtain economical results the form of the furnace for a given grade of coal should receive the most careful and expert attention.

BURKE SELF-FEEDING SMOKELESS FURNACE

Burke Furnace Co., Chicago, Ill.

This furnace is lined inside with fire brick, and above the grates a fire brick arch is formed, sealing the furnace. When the furnace is completed the cast-iron sections cover the entire furnace. Natural draft circulation due to the temperature of the furnace and the draft of the chimney, provides the proper amount of air which mixes with the hydrocarbon gases of the fuel, and as these come in contact with the incandescent fuel and heated arch, they ignite, and pass under the boiler without smoke.

The door in front of the furnace is for cleaning purposes only. By feeding the coal through the top of the arch, there is no chance for change of temperature in the sheets of the boiler or in the furnace. The coal is fed through hoppers on each side of the furnace, and its weight carries it down into the furnace, where it goes through the successive processes of distillation and ignition. All air for combustion is taken through the grates, which are so designed as to give the requisite amount for complete combustion.

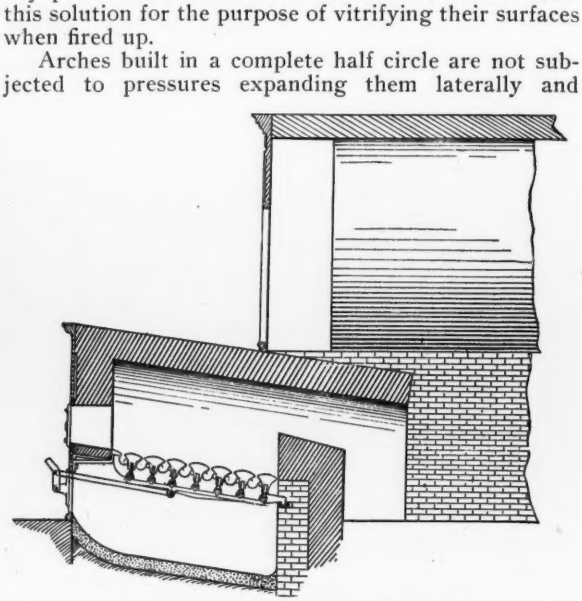
DORRANCE SMOKELESS FURNACE AND GRATE

Chas. J. Dorrance, Chicago, Ill.

In the Dorrance smokeless furnace natural draft only is used and the furnace is stoked by hand, by which method and the peculiar construction the best of combustion can be obtained. It is, properly speaking, a reverberatory furnace consisting of 1 or more arches to each boiler built in front, generally either wholly or in part, but sometimes built entirely underneath a water tube boiler.

These arches are constructed in perfect half circles of wedge fire brick laid up without the use of a trowel, each brick being dipped into a thin solution of refractory cement and rubbed down into place, making perfectly tight joints, and when completed a thin solution of this cement is run over the tops to fill in any possible crevices and the insides are washed with this solution for the purpose of vitrifying their surfaces when fired up.

Arches built in a complete half circle are not subjected to pressures expanding them laterally and



THE DORRANCE SMOKELESS FURNACE

springing the boiler setting when heated and when contracted, upon cooling, they do not cause the opening of joints between the arch and the boiler setting.

The furnace is supplied with air admission ducts over the fire but the larger portion of the air is fed through the grates. The grates used are the Dorrance rocking grates which are self cleaning and have large air admission area.

Smoke is prevented in this furnace by providing a brick arched roof over the bed of incandescent coal which prevents the gases from the coal from coming into contact with the cooler surface of the boiler until they have been completely combined with the oxygen of the air. The gases from the fuel striking this heated arch are burned and a white luminous flame is the result. When they have traveled the length of this long arched roof the smoke producing particles are thoroughly burned so that upon striking the boiler surfaces the combustion process is not interferred with.

The arched roof or ignition arch of the furnace, is built on a downward slope toward the boiler, and this increases the friction of the burning gases on the brick which aids in securing the best combustion.

THE SULLIVAN SMOKELESS FURNACE EQUIPMENT.

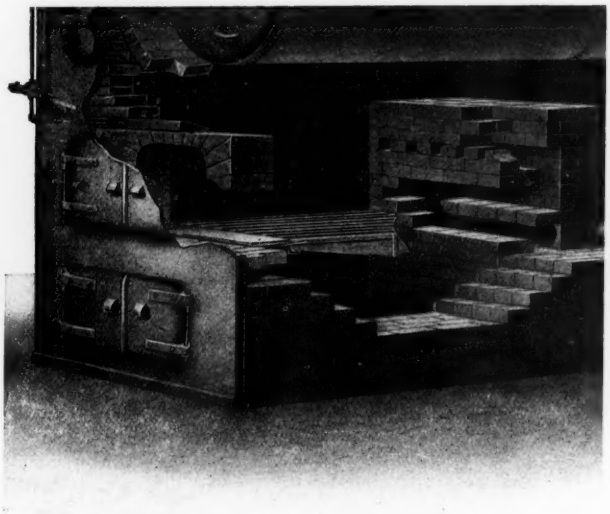
Greene, Ketchum & Co., New York, N. Y.

This equipment does not change the old furnace construction and can be installed in a few hours at a reasonable cost and without serious loss of time or interference with other furnaces. It is designed to furnish a maximum amount of heat with which to

generate steam by the use of bituminous coal as fuel, but with the entire absence of smoke or soot.

It consists of a specially built bridge wall or baffle plate, a steam retort buried in the front wall directly over the fire door arches, and an automatic time regulator to control the steam. The bridge wall is supplied with a transverse air passage, which is carried back and forth across the furnace several times to heat the air thoroughly and then terminates in a series of outlet ports just over the top of the fire bed. This supplies the furnace with sufficient oxygen at an extremely high temperature which mixes with the distilled gases from the fire to provide complete combustion.

The natural vacuum on the fire which varies with the amount of air required, serves to pull the air



SULLIVAN SMOKELESS FURNACE

through the air ducts and regulates the supply needed.

The air supply coming through the bridge wall cooperates with and balances the variable supply coming through the grate bars, and provides a perfect combustion at the proper places, directly over the grate bars.

The steam retort is especially designed for this purpose and is made of a composition which has great fire-resisting properties. It supplies the fire with dry steam, but only for a few seconds while stoking, when a temporary excess of hydrocarbons is thrown off, to hold them down and prevent their escape, so that the heated oxygen supplied through the bridge wall or baffle plate can control them.

Only a narrow face, 1⅜ in., of the retort is exposed to the fire, and even this is not flush with the fire bricks, so that the heat has no effect upon it. The steam outlet ports in the retort will therefore not become obstructed by the heat and prevent the discharge of the steam, and the retort is so designed and set that the steam will not come into contact with the bricks and cause them to disintegrate, but will empty out through the 1-16-in. ports evenly over the fire bed.

Entering into the center of the retort is a 0.5-in. pipe brought down from the dome or dry pipe which is provided with a valve operated by the automatic time regulator. When the regulator is suitably mounted the dry steam valve will automatically be turned on full as soon as the door is opened to feed the furnace.

When through firing and the door is shut, the valve immediately starts to close slowly and continues gradually to throttle the steam coincident with the reduction of the excessive hydrocarbons rising from the introduction of new fuel, until the steam, having performed its function, is finally cut off entirely.

PRODUCER GAS FOR SMOKE PREVENTION

Harris Smokeless Furnace Co., Nashville, Tenn.

For preventing smoke under a boiler, which will, of course, prevent smoke coming from the chimney, various schemes have been tried but all those which

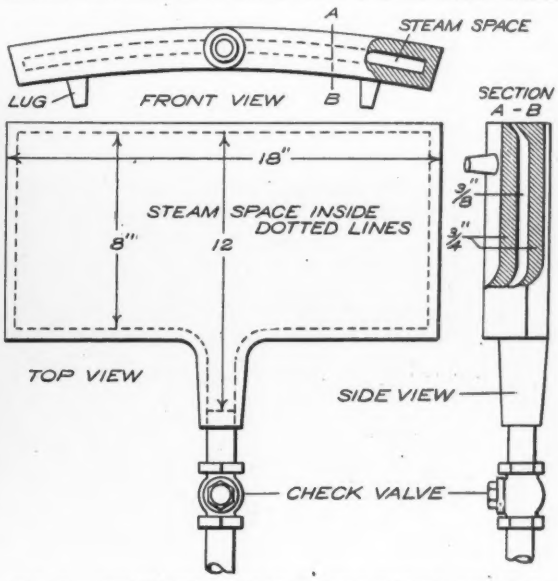


FIG. 1.—STEAM DISSOCIATOR OF THE HARRIS FURNACE

are logical have been worked on the basis of supplying sufficient oxygen at high temperature to burn all the combustible matter in the fuel.

The Harris Smokeless Furnace employs the method of dissociating steam in the firebox, thus furnishing by contact with the glowing mass of coal a water gas, as is done in the gas producer. The thin film of steam is passed slowly between hot iron surfaces, the

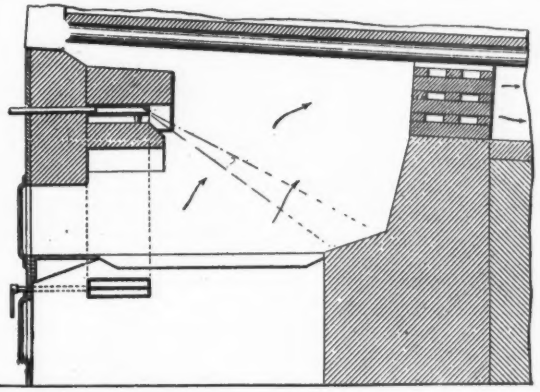


FIG. 2.—ARRANGEMENT OF DISSOCIATORS IN THE FURNACE

dissociator being as shown in Fig. 1. The temperature to which the steam is subjected is from 1,100 to 1,500 deg. F., and when the steam at this temperature issues into the presence of the fuel, carbon monoxid, CO, methane gas CH_4, and possibly other hydrocarbons,

are formed or, as we commonly say, producer gas is made.

Inside the firebox 2 of these dissociators are placed up between the tile fire arches and steam is led to them through a 0.75 in. main with 0.5 in. branches to each dissociator. The dimensions of the hollow space inside the dissociator are shown in the cross section. In the face of each dissociator are from 6 to 10 holes ⅛ or 1/16 in. in diameter to permit the passage of steam into the firebox.

Steam passing through the dissociator is heated to 1,100 to 1,500 deg. and becomes superheated so that its volume is more than 30 times that of saturated steam at boiler pressure. If the pressure, as is frequently the case, rises above that in the supply main, the check valve closes and the temperature will then rise still further in the dissociator. The jets will escape into the firebox until the pressure falls below boiler pressure, when the check will again open and

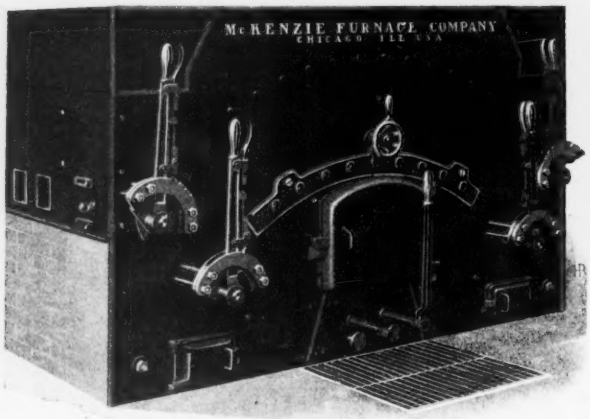


FIG. 1. MCKENZIE DUTCH OVEN MAGAZINE FURNACE

fill the dissociator. When steady operation is established, the regulating check will open just enough to supply the steam needed to pass out through the jets.

At this temperature the steam would not separate into oxygen and hydrogen except that it comes into contact with the heated coal and the gases from the coal. In these gases is an excess of carbon and both the oxygen and hydrogen have greater affinity for the carbon than for each other, so that the recombination is made and the water gas is formed. These gases are in condition, then, to burn readily on coming in contact with the heated air, which is supplied through passages surrounding the steam dissociators.

Thorough mixture of air and gases is secured by the checker work above the bridge wall. It will be seen that the jets from the dissociator are pointed downward in such a way that the steam issuing from these will pass through the products of combustion from the fire, while the air currents which enter around the dissociators, not being directed in this manner, will spread all through the firebox and thus mingle with the products of combustion and with the water gas formed from the steam. Proof of the effectiveness of the device is the complete satisfaction with it expressed by users as to reducing smoke and increasing efficiency.

WRITE IT ON YOUR HEART that every day is the best day in the year. No man has learned anything rightly until he knows that every day is doomsday—Emerson.

McKENZIE DUTCH OVEN MAGAZINE FURNACE

McKenzie Furnace Co., Chicago, Ill.

This furnace is designed for use with internally fired boilers, horizontal tubular boilers, and water tube boilers not exceeding 250 or 300 hp. The grate bars are set in the rigid frame work, at an angle of 45 deg. This furnace is arranged to be hand operated for small plants with a limited number of boilers, but for a great number of boilers, mechanical stoking can be added.

Coal is fed into the side magazine hoppers from above, either by gravity or shovel, the bottoms of the

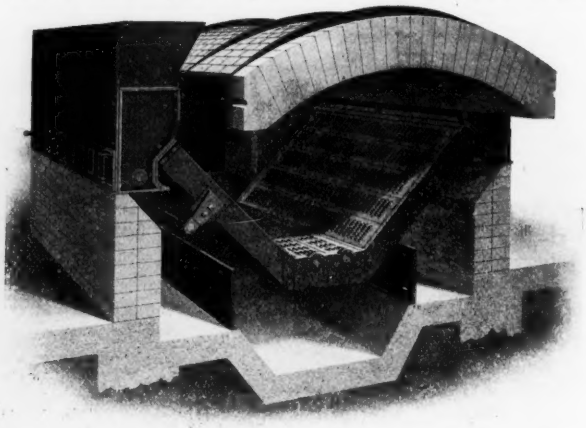


FIG. 2. REAR VIEW IN SECTION OF THE MCKENZIE DUTCH OVEN FURNACE

magazines being adjustable, and the coal feed into the furnace controlled by them; by moving the upper levers shown on the boiler front, the feed is set to anything required, or closed off entirely. Oscillating the second set of levers moves the entire grate surface at one time, thus breaking up the fire and increasing its capacity The dump grates at the bottom are double or single as may suit the conditions; their efficiency is equal to that of the grates on the sides, and fuel will burn on them just as satisfactorily as on the side grates. The dump grates are operated by the lever shown in the center on the front. Siftings from the coal fall into the side magazines and at intervals are thrown into the hopper. All ash goes to the pit below.

Air is admitted to the furnace at the sides to give equal distribution to the grates, and that furnished the bottom of the furnace and under the dump grate is admitted through the grating in the floor in front of the furnace. Air distribution over the top of the fires is controlled by the small hand wheel, through openings at the same radius as the arch.

The magazines in this furnace are removable, and but little brickwork is required. The arch is built of ordinary firebrick so as to simplify the maintenance when arches are to be rebuilt.

For small boilers and in places where large stokers are not adaptable this furnace has proved itself especially successful, giving high economy, with an absolutely clean stack; its simplicity, durability and convenience of handling make it a desirable construction for any boilers for which it is suited.

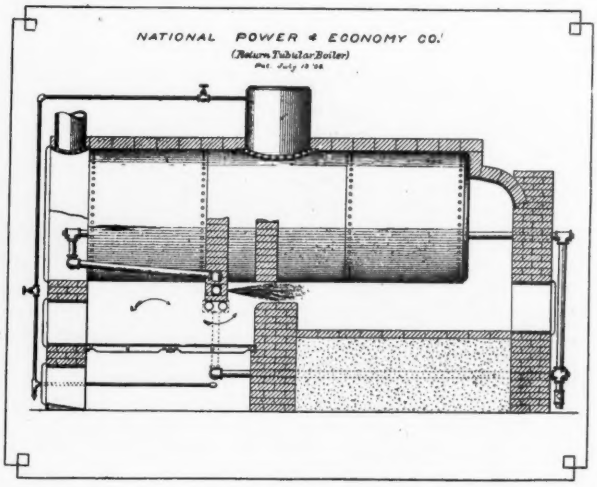
"THE LAW OF COMPENSATION IS—you pay for what you get, or you get what you pay for. You may spend your income now—and suffer later on. You may have what you want, but you must pay for it.

SYSTEM OF FUEL CONSUMPTION

National Power & Economy Co., New York, N. Y.

The essential features of this apparatus as applied to fire tube boilers and water tube boilers of the Heine or Franklin type are the water circulating system which supports a straight arch or baffle wall in front of the bridge wall, and which has imbedded in it a tube with jets injecting a mixture of air and steam. The circulating system is attached to a return tubular boiler by simply removing one of the tubes.

The circulation of the water in a return tubular



SYSTEM OF FUEL CONSUMPTION APPLIED TO A RETURN TUBULAR BOILER

boiler is aided by this system which makes it comparable with that in a water tube boiler. This straight arch reflects the volatile gases downward where they pass in a thin sheet over the bed of already incandescent coal which materially aids in the combustion. The remainder of the gases passes up through a narrow throat between the suspended arch and bridge wall before coming in contact with the comparatively cold boiler or tubes, and is here met by jets of steam and air which completes the combustion of the gases.

In construction these steam nozzles are flat which causes the jet to spread into a fan shape spray and thus secure a thorough mixture of the injected current of air, steam and volatile gases.

The application of this system to B. & W. water-tube boilers has now passed from the experimental stage. The circulating system is here used to support 2 arches extending in and downward from the front and rear of the grate chamber. In the throat thus formed the gases are met by jets of air injected from a set of nozzles imbedded in the inner face of each arch, the 2 sets being staggered relative to each other to procure a better mixture.

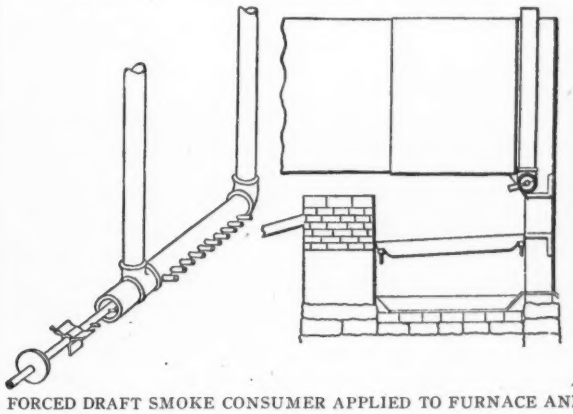
FORCED DRAFT SMOKE CONSUMER

National Smoke Consumer Co., Buffalo, N. Y.

The device which is here illustrated is designed to give better draft and more complete combustion in a boiler furnace. It consists of a 4 in. air pipe with a 0.5 in. steam pipe inside of it. The air pipe has 1.25 in. mixing tubes and the steam pipe has 1/16 in. steam jets. The small openings in the steam jets will show that the apparatus will use but little steam but the steam must be at full boiler pressure to do the work properly.

The air which is heated by contact with the steam pipe is distributed evenly over the fire, breaking on the bridge wall thereby setting the flame to roll and mix with the unburned gases making the combustion process complete. The air can be heated to any desired degree before striking the fire, which will aid much in the combustion.

The apparatus is easy for an engineer or fireman to handle and the steam jet pipe can be taken out in a moment for inspection by loosening a 3/8-in. set screw and the union while the boiler is in operation. Good working order of the apparatus is indicated when the air pipe is dark inside; if sparks or flame should be seen inside the air pipe, it is an indication that some steam jets are clogged. The operation of the apparatus can be observed by removing a rubber



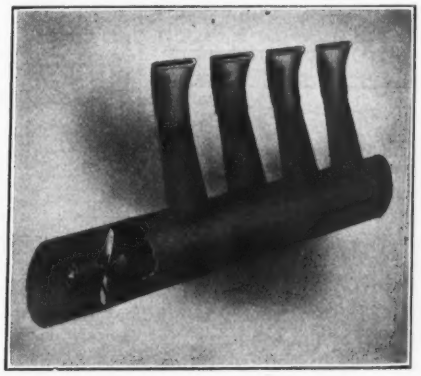
FORCED DRAFT SMOKE CONSUMER APPLIED TO FURNACE AND IN DETAIL

washer which covers the end of the air pipe which extends through the brick wall setting of the boiler.

NORTH HOT AIR BLAST SMOKE CONSUMER

Stephen H. North, Syracuse, N. Y.

This apparatus consists of 3 parts and is designed to secure complete combustion by furnishing sufficient air and mixing it thoroughly with the gases in the combustion chamber. The cylinder is about 5



VIEW OF NORTH HOT AIR BLAST SMOKE CONSUMER FROM REAR OF COMBUSTON CHAMBER

to 6 ft. long and 12 in. in diameter inside, of 3/16 in. steel and the connections are made of steel 1/8 in. thick. The nozzle consists of heavy cast iron 0.5 in. thick, diameter at the base 6 in. tapering upwards, expanded sideways and contracted front and rear forming an

elongated slot 0.5 by 7.5 in. giving the air a perfectly equal distribution no matter how many conduits are used.

In installing this grate first measure the distance that the bridge wall is back from the boiler front then drop down to the bottom of the combustion chamber, and cut a hole through the outside wall 12 in. wide by 18 in. high; slide in the cylinder. Send a man in to slip on the conduits and nozzle attached and roll back against the bridge wall. Then brick up the cylinder and it is ready for firing.

In connection with this an ordinary ventilating fan is used, merely to keep the cylinder filled with air, and costs about 5 cents per hour run for electricity. After the fire is started the nozzle becomes red hot, all other parts being covered with ashes.

The combustion chamber becomes hotter than the firebox for after the fire door is closed, ignition takes place and no combustible matter passes the nozzles without getting its share of oxygen.

The conduit covers a width of 12 in. A 50 hp. boiler would need 4, a 100 hp. boiler would need 5 and conduits are added as horsepower increases.

THE PARSON FURNACE SYSTEM

Parson Mfg. Co., New York, N. Y.

The Parson system of boiler furnace equipment comprises a separate steam blower applied to each boiler furnace; a means of superheating all the steam to be used by this blower; grate bars specially designed for the fuel which is to be used; bearing bars designed to eliminate binding with the result of warping of the grate bars; and a means of admitting under control such additional air as may be required for completing combustion above the grate bars. Where the setting of the boiler permits of it, a special gas combustion chamber is installed in combination with the bridgewall.

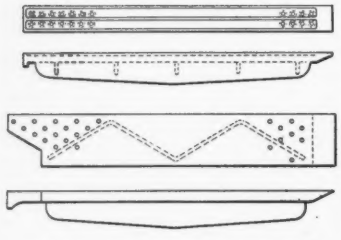


FIG. 2.—FORMS OF GRATE BARS EMPLOYED

In order to make the service uniform, a regulator is installed which controls the action of all the blowers under all the separate boilers and governs uniform service from them all.

Each blower consists of a single jet centrally located in its shell, and supplied with steam from superheaters installed in combination with each blower and usually in the side walls of the furnace. This jet is adjustable from being absolutely closed to its maximum working point and is locked at whatever point desired by means of washers which form the packing between the jet and its shoulder. This permits, by means of inserting or withdrawing washers, the most positive and absolute adjustment obtainable.

Special bars are designed for use with forced draft, as it was apparent that a bar built for natural draft conditions was not suitable for forced draft and such a bar used with forced draft might produce serious trouble, due to blowing holes in the fire so that cool air is forced directly against the boiler.

In the stationary type, there are 9 classes, with different percentages of air space and adapted to all fuels, the special features being the method of reinforcement, the locking of the bar on the center bearing bar while free at the both ends to ride on bearing bars designed specifically for that purpose, thus permitting expansion and contraction at all times. In addition to the stationary types are dumping and shaking bars which are installed in plants where arrangements are made for underground ash handling, or where loads do not permit the cleaning of fires during the run.

Wherever possible, the bridge wall is used as a means for introducing above the fire the additional air required for complete combustion, and on boilers of the horizontal tubular type of setting, a special gas combustion furnace is introduced and a special table to facilitate the cleaning of fires when stationary grate bars are used.

An additional blower is supplied to introduce such additional air as may be needed above the grates, built on the same lines as the larger blower which is used for the production of the draft of the boiler and the 2 are operated from the same steam line. This small blower is adjusted the same as the large one.

Automatic control of the operation of draft conditions is established by a regulator which is capable of controlling the operation of all the blowers on the same steam line. When the pressure drops from 1 to 2 lb., the blowers are put in service and remain so un-

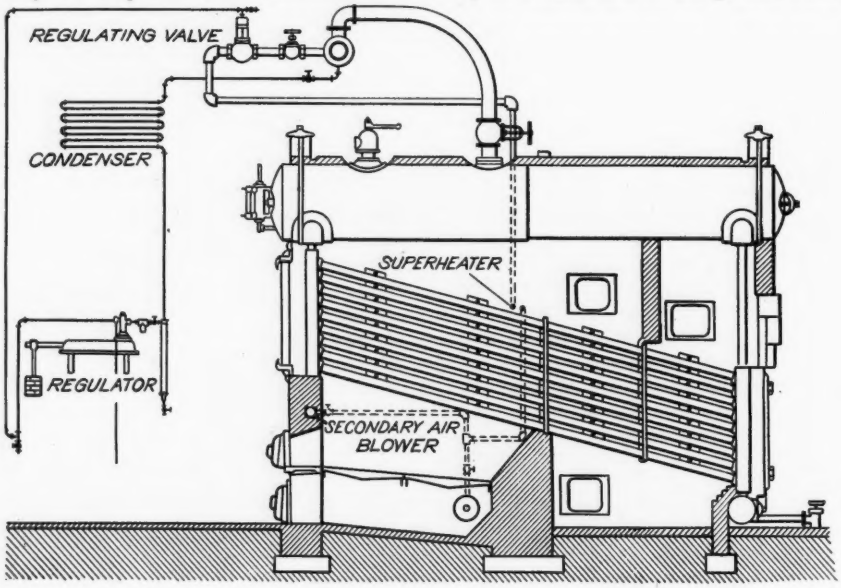


FIG. 1.—THE PARSON FURNACE APPLIED TO A WATER-TUBE BOILER

til steam has again returned to working pressure, at which point the regulator stops the action of the blowers until pressure again falls.

The Parson blowers are installed perferably in the rear of the boiler settings, at which point the air is driven by the blower into the ashpit, the doors of which are closed, the grates being the only point of exit for the air; thus the air is applied directly to the point necessary. Natural draft is used only in sufficient quantity to take away the burned gases; weather conditions are thus eliminated and positive conditions of draft under control are established, which are governable and changeable as desired.

Grate bars are installed in precisely the same position as those formerly in use; bridge wall conditions are changed only when settings permit of it and thus any boiler may be equipped in a few hours time.

SCHARF AUTOMATIC SMOKE PREVENTER

The G. H. Scharf Co., Ypsilanti, Mich.

The system for smokeless combustion installed by this company is a machine, automatic in its operation, injecting steam and air over the fire, when green coal

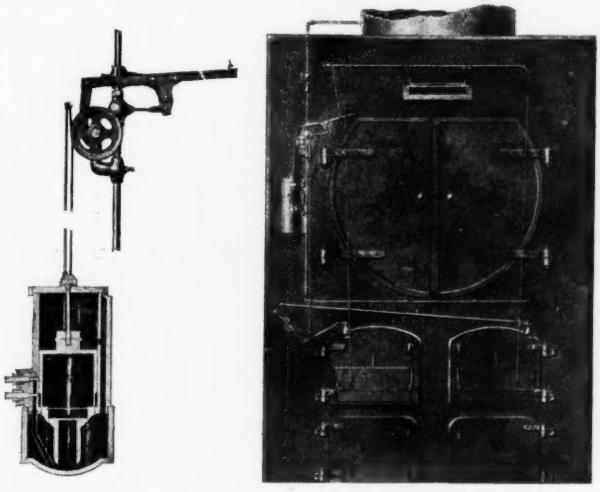


FIG. 1.—SECTIONAL VIEW OF SCHARF APPARATUS
FIG. 2.—BOILER SQUIPPED WITH SCHARF SMOKE PREVENTER

is thrown upon it, which combine with the hydrocarbon gases distilled at that time, forming a water gas, which will burn at a lower temperature than the hydrocarbons if left alone. The machine continues the injection of steam and air until the tuning device, which is set to shut it off at a predetermined time, does so; and at which time the furnace has regained its heat, and the incandescent fire is able to take care of its own gases.

Normal condition of the machine at rest is automatically assumed after a new fire has become incandescent. In the normal condition the steam and air are cut off, and the stack damper opened, allowing the cold air to enter the stack, which decreases the temperature of the uptake, and thereby checks the velocity of the draft past radiating surfaces, and retains the heat for steam making purposes.

In the illustration is shown the method of installing this apparatus. Opening the fire door for firing operates a lever, which in turn rocks a lift lever attached to a chain, raising a piston at the other end to the top of the dash pot, drawing up oil out of the tank through a check valve, thus filling the space under the piston, preventing the drop of the piston when the door is closed again. This upward action of the piston, and chain, revolves a sheave, bringing the pitman between the sheave and rocker lever to its highest point, thereby rocking the lever so as to open the steam valve for giving steam to the furnace through the jet section.

The other end of the lever, through chain connections, raises the fire door dampers, and allows the stack damper to close, giving the fullest draft for the new fire. These positions are slowly reversed to the normal condition, explained above, by leakage of the oil through the drain back into the tank below the piston. The amount of the leakage is determined by 2 needle valves located on the front of the dash pot, and governed according to the quantity and quality of coal handled, and so timed as to bring the machine to normal when the fire is smokeless.

When the piston is down, steam and air are shut off, and the stack damper opening allows the fuel saving properties of a decreased draft its fullest influence by keeping heat from the now incandescent fire under the boiler a longer time than otherwise, until the next fire. The needle valve controlling the flow of the oil when once adjusted needs no further attention. The act of firing starts the machine and the timing valves close it down at the proper time.

THE COE COMBUSTION AND DRAFT SYSTEM

Geo. H. Thacher & Co., Albany, N. Y.

The Coe combustion and draft system as applied to boilers of the water-tube and return fire-tube types consists of the following parts which are the same in design for all installations, certain of them, varying in size according to the conditions encountered in different plants.

A jet blower, located in the back or side wall of the boiler and connected with the fire-box by suitable air-ducts; a cast-iron air duct, connecting the blower with the ashpit; an air-tight ashpit; sectional shaking and cut-off grates; an improved reinforced cast-iron superheater, located according to the setting of the boiler at a point where the full force of the gases of combustion strikes it, usually projecting from the back wall, in the return fire-tube type or above the tubes directly in front of the first baffle plate in the water-tube type; a balance draft regulator, operating automatically the damper; a balance valve, which regulates admission of steam through the superheater to the blower; and the stepped cone pulley.

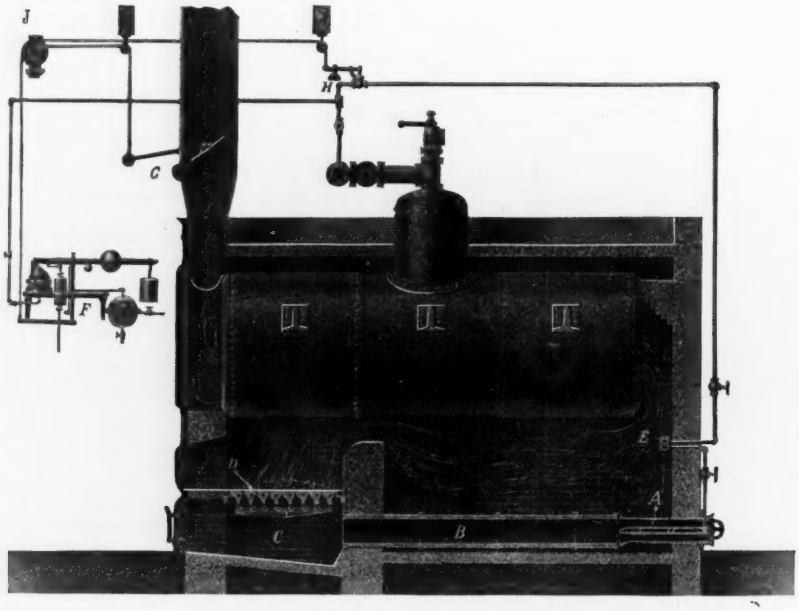
The application of these parts to the boiler and its setting appear in the illustration. When the Coe system is applied to steam furnaces the position of the damper in the smoke outlet of each boiler is adjusted so that it partially throttles the suction of the chimney maintaining the proper pressure in the fire chamber and boiler setting, the regulator holding this condition automatically at all times.

The main steam line is tapped at a point where dryness is assured and the steam is piped to the superheater which is exposed to the full force of the gases of combustion where it obtains a superheat of several hundred degrees. Thence it is supplied to the twin-tube jet blower and is controlled by and varies inversely with the steam pressure.

The highly superheated steam is injected into the twin tubes of the blower through small nozzles varying in size according to the amount of air necessary to be supplied, at a great velocity thereby reducing

the amount of steam used for this purpose to a minimum.

Just the proper quantity of air is supplied to maintain the rate of combustion to keep up the boiler pressure, and as there is not enough suction of the chimney to draw an excess of air through the fire, or through the fire door when opened, or cracks in the boiler setting, or porous brickwork, the temperature of combustion is not reduced by such excess of air nor are the gases diluted or the temperature lowered, resulting in the loss of efficiency of the heating surface, and carrying off of an excess of the heat up the chimney.



THE COE SYSTEM APPLIED TO BOILER

The Coe sectional shaking and cut-off grates add to the efficiency of this system. The air-space of the sections varying in size according to the fuel burned is designed to give perfect combustion with all grades of coal. This system can be applied to any type of boiler or furnace without change in the brickwork or boiler setting. No extra space is required and the outlines and dimensions of the boiler-room remain unchanged. The opening of the fire doors for the purpose of cleaning the fires is practically eliminated by the use of the shaking grates.

The gas formed by the mixing of superheated steam and air in the blower keeps the clinkers soft and porous and passes through the fuel bed uniformly. This system burns all grades and sizes of anthracite and bituminous as well as all other kinds of fuel that are used in a boiler.

The auxiliary air injected over the fire is delivered by a small single tube jet blower and the mixture passes through cast-iron boxes built in the side walls of the fire box where it gains temperature and thus more readily unites with the gases of combustion.

Steam is held automatically at any desired working pressure, the variation never exceeding a few pounds. Sudden heavy loads, as the peak-load in traction power plants, are taken care of. Steam is generated as fast and only as fast as needed. When the blower shuts off automatically, enough air is drawn in through the tubes of the blower to keep the fire alive. Consequently when a sudden demand is made upon the boiler for steam the fire responds immediately to the draft as the blower goes on, and within a minute or two the slight drop in pressure has been regained and is thereafter held without variation.

THE TWIN FIRE FURNACE

Water Arch Furnace Co., Chicago, Ill.

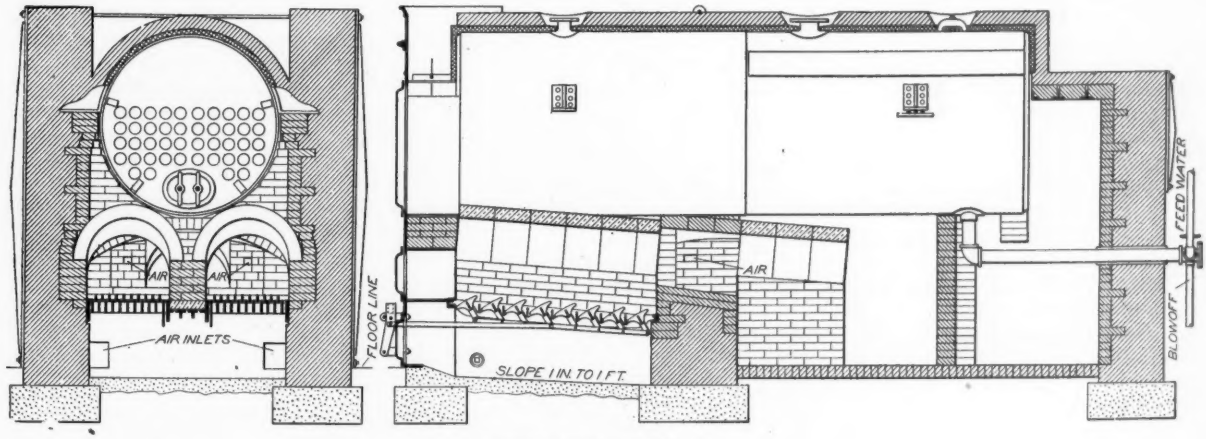
This furnace consists of 2 longitudinal arches, for 2 distinct fires, a connecting arch and a short retarding arch immediately back of the bridge wall. It can readily be substituted for the ordinary furnace in common use, under any size tubular or standard water tube boiler and is installed either entirely under the boilers or out in front in Dutch-oven type. In the construction of the arches a special tile is used, made from high grade of refractory clay, the thickness varying from 4.5 to 9 in. depending on the size of furnace and the width of grates, which the arch is to span.

For the support of the twin arches over grates, a ledge or shelf is constructed in the side walls of the setting. In the center between the 2 sections of grates, a fire tile wall is built on heavy bearing bars, supported at the ends by the bearing bar on the dead plate and the bar on the bridge wall, thus avoiding any obstruction to the free circulation of air in the ashpit. The connecting arch over bridge wall and the short retarding arch are constructed with fire tile similar to the twin arches in front.

Owing to the simplicity of design and construction, the operation of the furnace is similar to that of the common ordinary furnace. The fires are started and replenished by firing through 1 fire door to each arch the same as is in common practice with the plain furnace. In cleaning fires and removing clinkers from grates, 1 fire chamber is cleaned at a time, the opposite arch being worked in the regular way until a good fire has been rebuilt in the one first cleaned. This enables the fireman to maintain an even steam pressure and avoids lowering the temperature of the entire furnace during the operation of cleaning fires.

From the description of the Twin Fire Furnace it will be seen that the fire tile arches heat to a high

temperature and reflecting the heat upon the burning fuel and liberated gases, which, as they are thrown off, sweep the dome of the twin arches and are united at the bridge wall with a proper proportion of oxygen, admitted to each arch through the grate bars. The volatile products of combustion are not allowed to come in contact with the heating surfaces of the boiler but are retarded in their travel over the super-heated arches long enough to ignite and convert them into heat.



TWIN FIRE FURNACE

MECHANICAL STOKERS

TYPES, CHARACTERISTICS, ADVANTAGES AND DETAILS.

FROM what has preceded on smokeless combustion, it is evident that the operation of the furnace without opening the doors and with the fire-brick arch, which is usual in stoker installations, gives 2 important requisites for smokeless combustion and for high efficiency. Eliminating the blasts of cold air into the firebox will also reduce the excessive strains on the boiler structure and cut down repair bills.

As to the saving in labor of attendance, that depends largely upon the size of the plant. Unquestionably also the arrangement provided for supplying coal to the stokers has much to do with the reduction in labor cost. If fuel must be shoveled into the stoker hoppers, there cannot be much saving hoped for in cost of attendance. If automatic supply of fuel to the stokers is provided, the labor of attendance is much reduced, but this may be credited quite as much to the conveying plant as to the stoker plant. Mr. H. V. Coes says in Engineering Magazine that "Mechanical stokers save from 30 to 40 per cent of labor in very large plants burning over 200 tons of coal a week, 20 to 30 per cent in medium sized plants, 50 to 150 tons a week, and no labor in plants burning less than 50 tons a week." The cost of labor in making repairs, in cleaning fires and in up-keep of the plant will be, however, materially reduced.

Stokers may be divided into the chain grate, the front feed inclined grate, the side feed, the underfeed and the spread firing.

Chain Grates

More stokers of the chain grate type have been devised than of any other one class. For these, observations on practice made by the United States Geological Survey indicate that the depth of fire usually carried is 5 in. with western coals and 4 to 4.5 in. with eastern coals.

Measurements of draft showed that the average for 54 plants was at the furnace 0.19 in. of water, at the front tube sheet 0.43 in., at the rear of the boiler 0.43 in., at the base of the stoker 0.77 inch. Evidently in averaging there has been an impossible condition deduced for draft at the front and back of the boiler, for the average drop through the boiler was found to be 0.25 in. and from the boiler to the stoker 0.35 inch.

The Department gives as the results of its investigation that in operation of the chain grate it should be run so that volatile matter is all driven off by the time the coal has traveled ⅓ the length of the grate, the travel along the rest of the grate being used in burning the fixed combustible and heating air for the furnace. The grate should not be run so fast as to be hot when re-entering the furnace. Variable load may be carried with the chain grate by changing the thickness of fire, speed, and the damper position to suit the load, but draft should never be reduced below the certain minimum at which smoke will result.

Front Feed Stokers

Front feed, inclined-grate stokers are numerous and have given good account of themselves wherever properly installed and handled.

Professor L. P. Breckenridge, as the result of experiments at the Illinois Experiment Station, believes that the tile roof for an inclined grate stoker should slope up at a rather steep angle and that where such coals as those from Illinois and Indiana are used, a supplementary arch should be installed or a tile roof used under the front end of the boiler.

Observations of the Geological Survey on a large number of plants showed that the average ratio of heating surface to grate surface for this type of stoker was 40 to 1, and the average rate of combustion of coal as received, 15.6 lb. per square foot of grate per hour.

The drafts ran for averages as follows: In the furnace 0.26 in. of water; at the rear of the water-tube boilers 0.44 in.; at the base of the stack 0.76 in.; the

average drop of draft through the water-tube boilers was 0.16 in. and through the return tubular boilers 0.33 in. Depth of fire on these stokers ranged from 3.5 to 7 in. and the grate surface was always considered to include both the sloping grate and the dumping grate at the bottom.

An advantage of this type of stoker is that the fuel bed is entirely visible from below so that the condition of the fire can be observed at all times and it can be broken up if necessary, thus allowing the stoker to be run at a higher rate of combustion than would otherwise be possible.

The Side Feed Type

Side feed stokers, which as a rule have inclined grates at either side and a shaking or dumping flat grate at the bottom of the furnace, have given good results.

Side feed stokers have the advantage of a large coking space per foot of grate area and large combustion chamber. Care should be taken in installing stokers of this class to make ample provision for getting rid of the ash as the grate at the bottom is likely to be low and the depth of ashpit, therefore, not great.

When used with a return tubular boiler it has usually been found more satisfactory to set this type of stoker, or, in fact, any type for that matter, in a Dutch oven. In the investigations of the Geological Survey it was found that the average ratio of heating surface to grate surface was 59.1 to 1. The draft in the furnace varied from 0.15 to 0.25 in. At the rear of the boiler it ran at 0.43 to 0.51 in. and at the base of the stoker from 0.58 to 0.81 in.

Underfeed Stokers

In the underfeed stoker is found a design of furnace which conducts all the volatile gases directly through the incandescent fuel bed, thus bringing them to a high temperature so that they are readily ignited when mixed with the proper amount of air. They are, therefore, able to handle high overloads with little, if any, smoke production.

The underfeed stoker requires forced draft to drive the required air through the fuel bed, and this gives absolute control of the air supply which can be so arranged that it will be automatically increased with the rate of firing of the stoker. But little space is occupied by this type of stoker which is usually installed without the firebrick arch. Observations of underfeed stokers by the Geological Survey show that 700 to 800 lb. of coal per stoker is about the limit of good practice, heavier feeding than this being likely to produce undesirable results.

Draft conditions were found to average at a pressure in the ashpit of 2.45 in. of water and draft in the furnace of 0.33 in., draft in the rear of the boiler 0.48 in. and at the base of the stack of 0.8 'in., giving a drop through the boiler of about 0.15 in. and from boiler to stack of 0.3 in.

Observations of the Survey showed that at plants equipped with this class of stoker even where the loads fluctuated so widely that fires were banked and then broken up and put in service quickly, a minimum of smoke was made, the combustion being practically smokeless at all times. They advised that on account of the ash being nearly all fused into large masses so that it must be pulled out from the dead plate, this plate should be made wide enough to permit cleaning fires without breaking up the fuel bed.

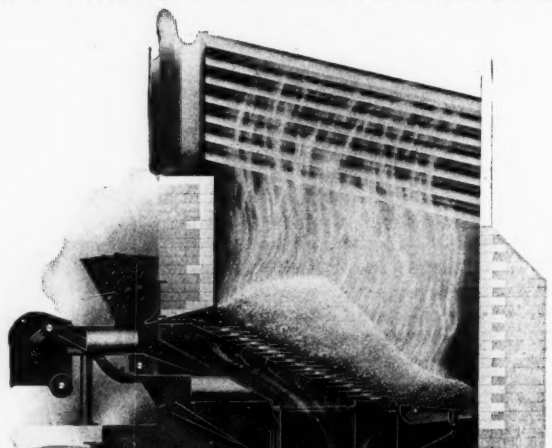
Spread Firing Types

Spread firing stokers are, as a rule, built for installation with the grate already in use under a boiler. They are intended to take the place of manual labor in throwing the fuel upon the fire and operate on a number of different mechanical principles. The efficiency of a furnace equipped in this way will depend, of course, upon the arrangement of the grate, firebox and combustion chamber, the same as if the fuel were fired by hand, but the additional advantage will be gained that the feeding of fuel can be uniform and regular, the firing door need not be opened to admit blasts of cold air, and in most designs the feeding can be regulated so as to throw a greater or less amount of coal on any part of the fire, as desired. Such figures as are available in regard to performances of this type of stoker are given in the descriptions of the various individual makes.

THE TAYLOR GRAVITY UNDERFEED STOKER

American Ship Windlass Co., Providence, R. I.

The Taylor stoker which is designed to increase boiler capacity by creating furnace conditions such that 200 per cent and over of rated boiler capacity is obtainable for continuous service at correspondingly high boiler efficiencies, consists of a series of inclined retorts or fuel magazines, supported upon a blast box or air reservoir. Inclined air ducts or tuyere boxes form the sides of the fuel magazines, and these are capped with specially formed tuyeres through which air is forced into the fuel. The coal descends from



SECTION OF TAYLOR STOKER INSTALLED

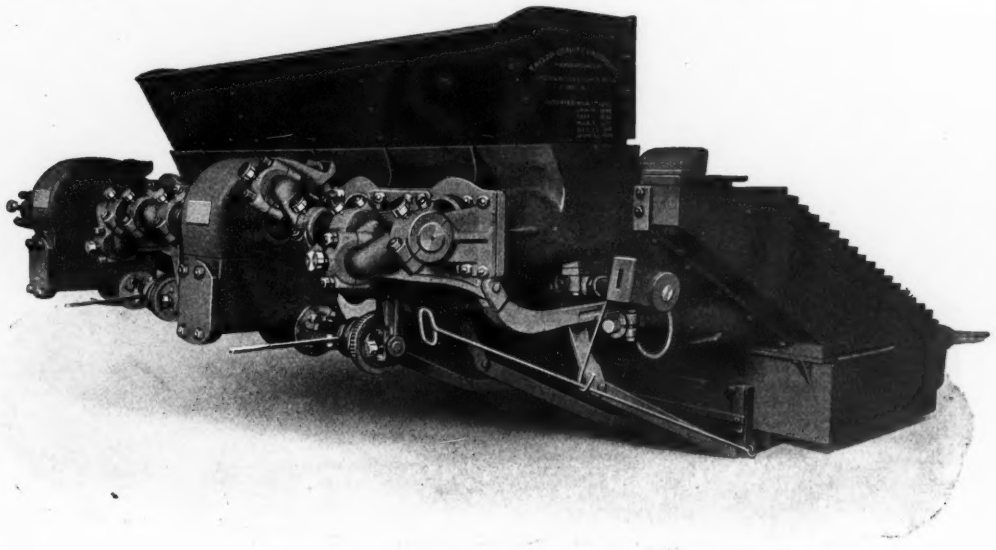
the hopper above to powerful cylindrical rams. There are 2 rams to each retort. The upper ram receives the coal from the hopper and forces it into the top of the retort. The lower ram receives its charge only as the coal descends by gravity from the upper ram, and it feeds just a sufficient quantity to maintain an even depth of fuel bed. The stroke of this ram can readily be adjusted to burn any coal properly.

The rams are actuated by connecting links and bell cranks driven by crank shafts which are connected through double worm gearing with a speed shaft, driven by the engine operating the blower.

The dumping plates, which are a combination dump and fire guard, are hung on the rear of the wind box. They are operated from the front of the stoker by

means of a shaft, lever and link. These plates are dropped by disengaging a pawl and catch in the connecting link. They are raised by a hand lever, and the pawl engages automatically when they are in position.

The driving rams can be readily withdrawn by the removal of a pin and without dismantling the stoker. The crank shafts are in sections connected by universal couplings, and are secured to the main driving wheel in the power box by companion flanges which are easily disconnected. The power box is a complete unit with removable covers and caps of ample size and with all driving gears interchangeable. The tuyeres



FRONT VIEW OF TAYLOR UNDERFEED STOKER.

are all interlocking, and no bolts are required to hold them in place.

The dumping plates are made in sections and can be taken off by removing the keepers. The stoker is driven by a positive connection from the main blower engine, which is of ample size to drive all the stokers of an installation.

The durability of this stoker can be ascribed to protection from the heat, elimination of large frictional resistances and massiveness of the vital parts.

The most important consideration is that the cast-iron parts of the furnace are at all times protected by green fuel. As a further protection, all fuel-supporting parts—tuyeres, coal plates, etc.,—are air cooled and there are no moving parts in the furnace.

Wear of the moving parts is reduced to a minimum, as the speed of the crank shafts and plungers is extremely slow (approximately 2 minutes for each revolution), and the power box reduction gears run in a bath of oil.

The Taylor gravity underfeed stoker with its inclined furnace deposits all the refuse in the rear. This allows the retorts or fuel magazines to be placed close together and permits the use of a large number of retorts per boiler. The air enters through a large tuyere area and is furnished at a low pressure, which insures a thorough mixture of the gases and therefore complete combustion.

Air is supplied to the stoker by a volume blower, which is in fact an essential feature of this system of stoking, as it is this which permits a proper regulation of the supply that is impossible with natural draft.

Smoke in the Taylor stoker is eliminated because the fuel is completely burned in the furnace. The reasons why the Taylor secures this result are as follows:

1. It is an underfeed stoker.

2. It employs a large number of retorts, and, therefore, burns a comparatively small amount of coal per retort per hour. The coal has ample time to coke, and the volatile gases which cause smoke unite with the air as it enters through the tuyere openings, and form a combustible mixture below the body of the burning fuel. This is completely burned in its passage through the incandescent bed.

3. It supplies the coal and the air in exact ratio, which is scientifically determined and which remains constant at all times and under all conditions.

THE UNIVERSAL CHAIN GRATE STOKER

Oscar Barnett Foundry Co., Newark, N. J.

Structural material is used throughout the entire frame work of this stoker, and the sides are permanently supported within the furnace chamber, giving ample flexibility and strength to the structure. Cross rods are supported by the sides and upon them peddler wheels are loosely mounted to carry the endless chain cables. Upon the rear of the frame a heavy shaft is mounted, which supports similar peddler wheels, over which the chains return to the front of the stoker.

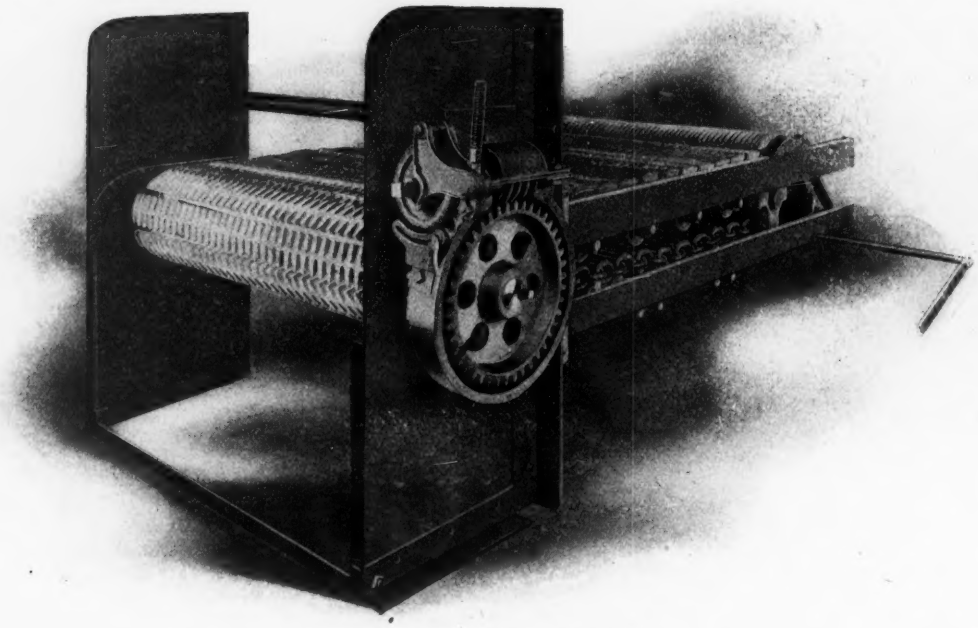
At the front of the stoker another heavy shaft is mounted in bearings, which are supported by the housings and end plates of the hopper, the tension of the chain cables being adjusted by means of wedge plates placed at each end of the stoker.

Grate bars are attached to the chain cables by shoes that pass into and are held on the inside of the links. The shoes are held to the grate bars by spring cotters, and the grate bars are usually the full width of the stoker, moving at the rate of 5 to 10 ft. an hour. The construction is such that a bar may be changed at any time necessary while the stoker is in operation without drawing the fire.

Supporting rollers loosely mounted upon cross rods, supported by the side frames, are supplied under

the stoker, upon which the faces of the grate bars are carried during their return journey. The transmission medium is a worm and gear enclosed in a casing, forming a part of one of the propelling shaft bearings. A ratchet wheel is usually mounted upon the worm shaft enclosed by the ball and socket joint bracket, and to which is connected an eccentric propelled by any motive power.

At the rear of the stoker is mounted a flexible bridge upon which the ashes and refuse are transferred to the dump plate from the traveling grate. This dump plate is of a solid and blank construction and when closed is air tight.



UNIVERSAL CHAIN GRATE STOKER

The fuel goes from the hopper through the fuel port, and is immediately ignited; in its travel to the rear of the stoker, the fuel is kept loose, and it is to a large extent prevented from coking into a solid mass by the irregular movement of the grate surface and chain while traveling over and between the peddler wheels.

This stoker is manufactured under a license from Paul L. Crowe.

THE CONTINENTAL CHAIN GRATE STOKER

The Continental Stoker Co., Chicago, Ill.

The complete chain grate is a combination of grates, links and grate bars, the grates are of an improved type with dove-tail and semi-circle recess for locking each grate in position; this dove-tail being inserted into the openings in the links and bars, a rod passing through the cored hole locks each grate into its proper position.

This type of grate has no other strain upon it than the heat of the furnace and is able to expand and contract freely in all directions without causing any strain upon any other portion of the chain, there being no pulling strain on it, also no crowding together or apart from each other, each grate being securely locked into its proper place, which maintains the proper distribution of air, and also prevents loss of coal or excess of air. The grates are self cleaning and in repairs they are very easily removed and replaced, as there is only one rod to contend with. The rod has no other duty to perform than merely to act as a key to each grate, the grate proper is made in one style, one size, and is interchangeable.

The chain is constructed of heavy, substantial links separated and bolted to cast iron bars. These bars act as supports for the grates; 3, 4 to 7 rows of links are used, the number depending upon the width of the stoker. All holes in links and bars are drilled to jig so as to make a perfect pitch chain, each link has 2 rollers attached for conveying the chain upon upper and lower tracks, the links and bars being completely protected from the heat of the furnace by the grates above and intervening air space between.

The frame consists of 2 heavy cast iron side frames connected to 2 heavy hopper frames, braced by 4 substantial cross girders transversely to the frames, and

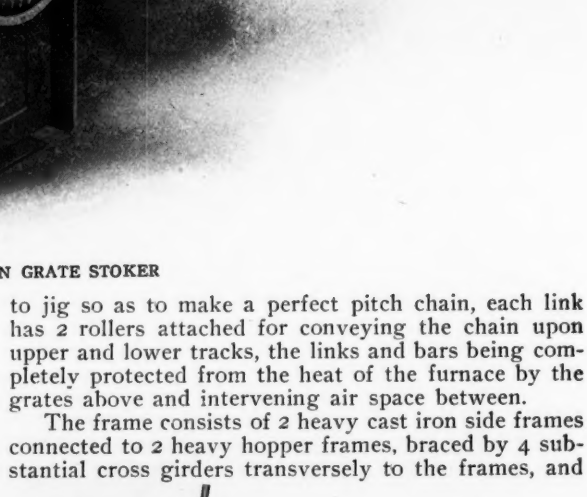


FIG. I.—THE CONTINENTAL CHAIN GRATE STOPE

2 3 15/16-in. steel shafts upon which are mounted and keyed the sprocket wheels, which impart the traveling motion to the grate surface. The frame is mounted upon flanged wheels which rest upon rails set under the furnace so that the entire machine can readily be withdrawn from under the boiler. The driving mechanism is so constructed that it utilizes the up-

ward and downward stroke of the eccentric and able to produce different speeds.

The coal is fed through a hopper of the full grate width in a layer of a depth regulated by a hopper gate which can be raised and lowered. The coal is ignited near the front end of the furnace and is carried backward slowly, the speed of the grate being adjusted so that the time of travel is sufficient for complete combustion of the fuel, the ash and refuse being

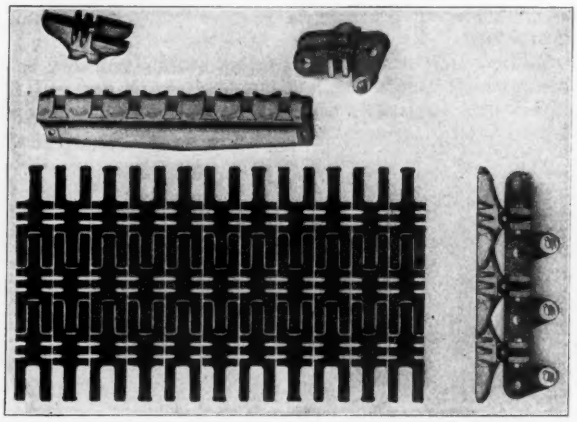


FIG. 2.—PARTS OF CONTINENTAL CHAIN GRATE

carried over the back end where they fall into the ash-pit. At the front end, a fire tile improved flat arch facilitates coking of the green fuel as it enters and also furnishes heat to burn the volatile gases evolved.

DETROIT AUTOMATIC STOKER

Detroit Stoker Co., Detroit, Mich.

The Detroit stoker is built with 2 distinct methods of feeding the fuel, the worm coal conveyor method and the reciprocating method.

This conveyor is ball bearing and is of such design and construction that it distributes the coal on the coking plate at the top of upper ends of the grates on either side of the stokers. At this point the hydrocarbon gases are released and mixed with the heated air which is admitted in jet form through the arch boxes and air chambers in the proper proportion to produce complete combustion. The double fire brick arch through which this air passes, covering the entire stoker and extension beyond the rear grates, assists materially in bringing the operation up to the highest point of economy.

The conveyor is designed to deliver a larger portion of the coal to the rear of the grates, at which point more fuel is consumed than in any other portion of the furnace. To make this conveyor strong and durable a heavy steel shaft is cast in the center of the conveyor which makes it impossible to break, unless car links or other foreign substance should be placed in the hoppers. This conveyor, while it is not designed for a coal crusher, will handle run of mine coal provided the large lumps are broken with a hammer, as they should be when firing by hand.

Either or both conveyors can be thrown out of commission during operation, by disconnecting the clutch gears from the small lever in front of the hoppers, thus stopping or regulating the feed of coal on either or both sides of the fire.

The coal magazines are cast in one solid piece without openings, thus preventing the fine coals from sifting through into the ash or dust pits.

The Detroit stoker, as built with the reciprocating feed, is designated to meet the requirements for large size units when the conditions are better adapted for feeding the coal by gravity, elevating it on top of a

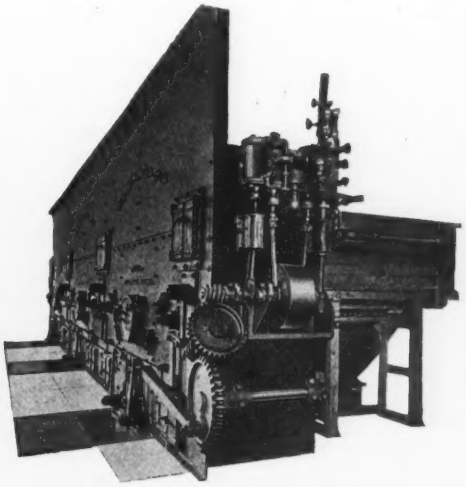


FIG. 1.—DETROIT STOKER WITH BAR DRIVE AND RECIPROCATING FEED

Dutch oven or extension front setting and when the requirements for steam are extremely variable or a peak load is demanded on short notice.

Connections are made by the use of links which are interchangeable and can be removed during operation to regulate the movement of the grates and clinker crushers as well as the feed of the fuel in accordance with the requirements for steam. The pusher boxes operating parallel with the coking plate push the coal out at intervals.

There are 2 styles of grates, stationary and vibrating. On the stationary grate are ledges or openings

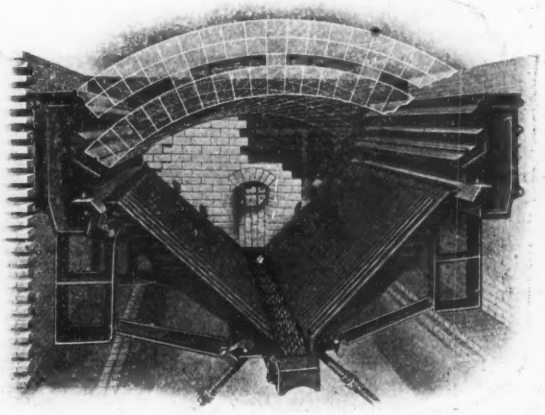


FIG. 2.—REAR VIEW OF RECIPROCATING FEED DETROIT STOKER

for admitting the air at the upper end under the coking coal. The vibrating grate operates continuously and automatically, preventing the clinkers from forming on the grates, and at the same time moving the bed of fire down towards the center of the clinker crusher.

These grates can be disconnected during operation, thereby causing the vibrating grates to remain station-

ary as may be desirable when using the non-coking coal.

Air for combustion is taken in through the openings in the stoker fronts and passes into the arch box through special chambers, which prevents the coal magazines and parts from becoming heated.

The clinker crusher is composed of a row of cast iron disks which rotate towards each other, having a backward and forward motion, being operated by the bar in front and can be discontinued at will. The grinding motion of the disks makes them easily operated and clinkers readily crushed and the entire clinker crusher can be operated by hand during operation if desired. Each crusher disk is easily replaced when burned or broken without disturbing the others.

THE ERIE STOKER

Erie Foundry Co., Erie, Pa.

The Erie stoker differs from other fuel feeding devices in several important features, but most conspicuously in that it is located entirely outside of the boiler furnace. The ultimate purpose of its designer was to develop a machine which would take the place of the man with the shovel, the thought being that, if a machine could be devised which would deliver the fuel over the grates uniformly without opening the doors, an immense saving could be obtained in both coal and labor.

The principle involved is apparent from the illustration. A generous steel hopper contains, at the bottom, a small screw conveyor which is driven by a chain and sprocket from the same steam motor which actuates the main part of the appliance. This conveyor works the coal to the front of the hopper where an opening in the bottom permits it to drop by gravity into the feed box or trough. This trough is bolted to an extension of a cylinder in which reciprocates a piston, the piston being driven forward into the trough at each impulse.

The impact of the piston or plunger, upon the coal falling into the trough from the hopper, throws the coal into the fire box. The proper diffusion of the fuel over the grates is obtained by the 3 degrees of speed of the piston and by the deflector which is located at the front of the trough immediately inside of the fire box. This variable stroke is given to the plunger by means of a rotary valve, 3 separate steam ports leading from this valve to the rear end of the cylinder, and 3 choke plugs, one for each of the steam ports.

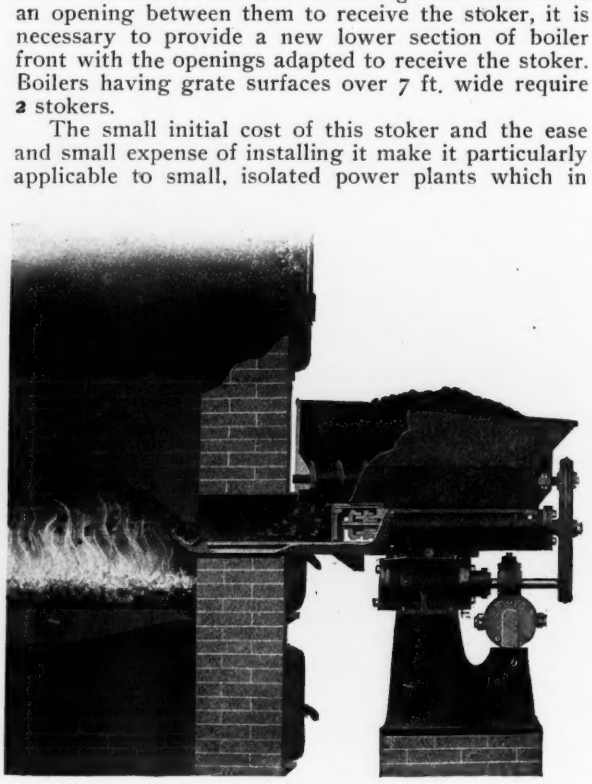
The office of the 3 choke plugs is to vary the amount of steam reaching the rear end of the cylinder through the various ports, and thereby give a variable stroke to the plunger. The valve operates in a rotary manner, each of the ports stopping full open in front of its corresponding steam passage in regular succession. By choking down the steam with the choke plug nearest the rear of the stoker until the port is almost closed, there is obtained a very light stroke of the plunger, thereby distributing the coal over the grate near the fire door.

The other 2 choke plugs operate in the same manner, each taking its respective turn. They are adjusted so that more steam is admitted on the second stroke than on the first, thus distributing coal over the middle portion of the grate and more steam is admitted on the third stroke than on the second, thereby scattering the coal over the rear end of the grate. By this adjustment of the choke plugs any arrangement of distribution can be obtained that may be desired.

The conveyor is controlled by a small reciprocating steam motor which also operates the valve that controls the speed of the piston or plunger, thus giving a uniform amount of coal for each stroke of the plunger.

In the case of boilers having only 1 fire door, or where the fire doors are too close together to admit of an opening between them to receive the stoker, it is necessary to provide a new lower section of boiler front with the openings adapted to receive the stoker. Boilers having grate surfaces over 7 ft. wide require 2 stokers.

The small initial cost of this stoker and the ease and small expense of installing it make it particularly applicable to small, isolated power plants which in



THE ERIE STOKER

the past have been to a large extent prohibited from the use of mechanical stokers on account of expense. On the other hand this stoker is applicable to boilers of any type and any size.

THE ERIE TRAVELING GRATE

Erie Foundry Co., Erie, Pa.

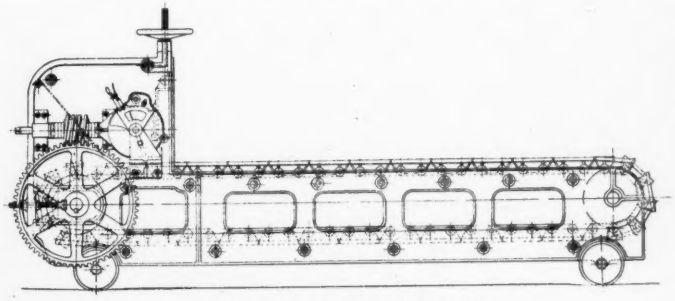
The grate surface consists of a large number of small links of considerable depth, mounted on a fixed supporting frame, and traveling in the form of an endless chain over supporting rollers. The motion is imparted by the sprocket wheels, which are mounted on a driving shaft and engage with the rollers on the rods supporting the grate links which form the chain.

The fuel is fed in at the front end of the furnace, through the hopper, and immediately becoming ignited under the igniting arch, is carried back towards the rear of the boiler by the traveling grate surface, passing through the successive stages of coking, distillation and combustion, until it is discharged over the end of the traveling grate into the ashpit or on to the attachment. The grate bars in passing over the back shaft for their reversal travel, automatically shear all clinkers, thereby thoroughly cleaning the air passages and the maximum amount of air space is always obtainable.

The motion of the driving shaft is derived from an enclosed ratchet, worm and gear, which can be

located on either side of the front end of the traveling grate, and is transmitted through an eccentric from the line shaft. The amount of coal fed is regulated by raising or lowering the cast iron feed gate lined with fire brick, on the inside facing the igniting arch. This regulation, in connection with increasing or decreasing the speed of the grates, provides for any variation in intensity of fire which may be desired.

The frame work consists of heavy cast-iron frames, well braced, to meet the requirements of hard service. In grates exceeding 7 ft. in width there is provided a center support for the upper roller shafts. Diaphragms are provided in the frame work between the chains to regulate the amount of air through or around the rear portion of the grate, where the fire is spent and the ashes discharged. Access is obtained to the interior of the furnace by lowering the front of the



THE ERIE TRAVELING GRATE

hopper, and raising the feed gate, or, if desired, the whole stoker can be withdrawn from under the boiler along the supporting rails.

GOETZ & FLODIN STOKER AND SMOKE CONSUMER

Goetz & Flodin Mfg. Co., Chicago, Ill.

The feeding hoppers of this apparatus are hinged so that they can be tilted forward and the doors opened while the flues are being cleaned. These hoppers

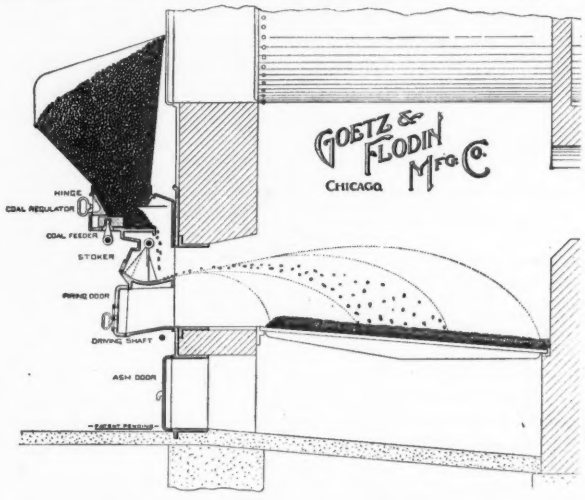


FIG. 2.—SECTIONAL VIEW SHOWING OPERATION OF GOETZ & FLODIN STOKER

may be any size, and for ordinary purposes will contain enough coal for 2 hr. feeding.

Coal drops to the feeder which automatically permits a certain amount to drop in front of the stoker, the amount of coal fed being regulated by the feeder to suit any conditions whatever. The stoker, which consists of a wing, then throws the coal on the fire.

The interesting feature of this wing is that the springs which are seen in the middle of the illustration are so snapped off that at the first throw the wing throws the coal as far back as the bridge wall, the second throw to the middle of the grate and the third time near the front; then way back again and so on. This recurring regular and continuous feeding of fuel

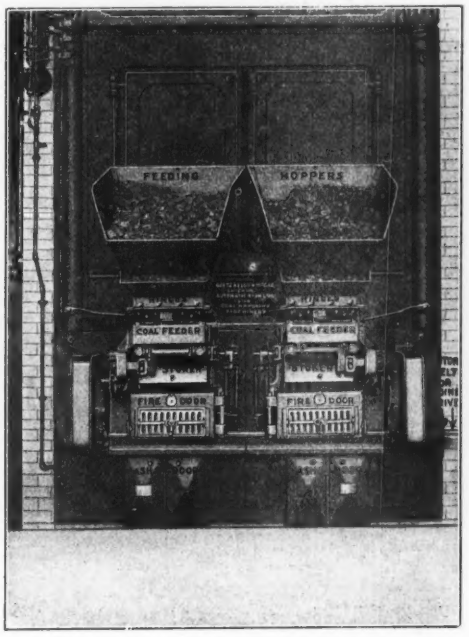


FIG I.—GOETZ & FLODIN STOKERS ATTACHED TO BOILERS

in proper amounts is the ideal method of firing and insures against careless and irregular hand firing.

Another important advantage is the fact that hand firing of rubbish, wood, etc., is not at all interfered with, and can be done at any time while the automatic stoker is in operation.

The actual power required per boiler is 0.5 to 1 hp. depending on the size boiler and to operate the apparatus nothing else is necessary than the small steam engine which is provided with the stoker. It is adaptable to any style grate and furnace and is made to fit any style front.

THE GREEN TRAVELING LINK GRATE

Green Engineering Co., Chicago, Ill.

This form of stoker consists of a moving endless chain mounted on a frame with provision for the continuous and uniform feeding of coal into the furnace, both fuel and grate traveling together. The operations of feeding the coal into the furnace, carrying it through the progressive stages of combustion, removing the ashes and clinker, and maintaining a clean grate surface and free supply of air are automatically performed. This arrangement is largely independent of the quality of fuel, being quite successfully used with the poorest and cheapest coal obtainable.

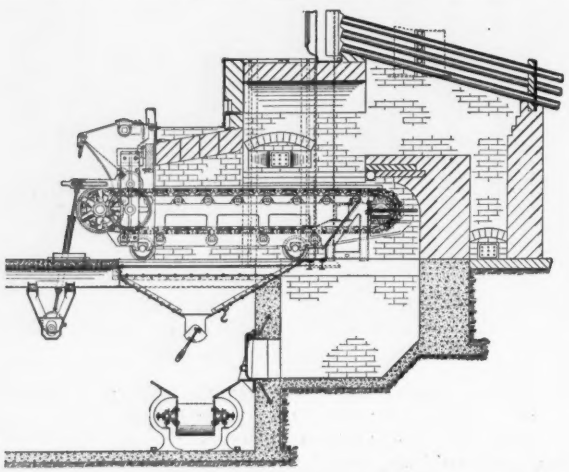
In the latest type of these grates the side girders of the frame are entirely removed from the furnace fire and increased uniform air supply provided. The staggered arrangement of the links forming the chain

clears completely all of the ashes from the air spaces of the chain at every turn around the rear and front sprockets.

To meet the requirements of hard service the frame work is well braced and stiffened. Center supports for the upper rolls and the front and rear sprocket shafts are provided in all stokers exceeding 7 ft. 6 in. chain width, and the gearing connections to the front sprocket shaft are double drive, having a gear at each end of the sprocket shaft. This overcomes the defect of excessive shaft torsion and the creeping ahead of 1 side of the chain, unavoidable in wide stokers driven from 1 side.

The rear cross girder is fitted with a heavy plate on the under side, and in machines of over 7 ft. 6 in. width is a built-up box girder on which the accumulated ashes form an effective insulation from radiated heat. This girder in connection with the rollers just above and below and the air baffles on the links of the chain prevent the passage of air through or around the rear portions of the grate, where the fire is spent and the ashes discharged.

The links forming the chain have slotted openings and the connecting bars oval in cross section will



GREEN TRAVELING LINK GRATE

pass through the slots in the links in 1 position, but lock the links when the bars are slightly turned and the binder links and cotter pins are applied. Any link can be removed and replaced without breaking the chain or removing the bars or interfering with the service, by detaching the outer binder links and turning the bars in line with the slots of the links.

In all grates exceeding 7 ft. 6 in. chain width the chain surface is double web and comprised of 2 continuous sections with the connecting oval bars of each section extending half way across the grate and fitted in the inner end by special binder links, which do not require removal in order to turn the oval bars. The driving links set centrally over the teeth of the driving sprockets, thus doing away with any tendency to create looseness laterally due to a wedging effect of the sprocket teeth.

The driving mechanism, consisting of a ratchet, cast-steel pawls, and cast-steel spur gear train, is babbitted in a strongly braced, self-contained frame independent of, but bolted to the stoker front side frames and readily permits quick adjustment within a wide range. The pawls of the operating ratchet may readily be locked out of action. The eccentric connections to the operating line shaft which are placed either above or below the floor line, are made through a long relief spring.

Requirements for hard firing are made by regulating the feed gate, which is provided with a tile lining in the furnace side, so designed that each tile might be replaced independently of the others. Creeping of the fire back into the coal hopper is effectually prevented by removable shields, so placed in the grate as to form a ventilated air chamber between them and the outside of the grate. These shields extend slightly below the bottom of the tile to protect them from wear and fix the thickness of the fuel bed.

The quantity of the fuel or thickness of the fuel bed is regulated by the feed gate, which gate is supported from a heavy square shaft between vertical guides and adjusted by the worm and sector attachment on the side frame opposite the driving mechanism.

An ignition arch is provided with these grates, the construction and application of which is shown in the illustration. It is of the ventilated flat arch type giving uniform ignition and combustion the full width of the furnace and allowing local repairs to any part without undue loss to the use of the boiler. The method of supporting the arch tile removes all strain incident to effects and eliminates the side thrust on the side walls of the setting.

ILLINOIS CHAIN GRATE STOKER

Illinois Stoker Co., Chicago, Ill.

Designers of this chain grate stoker had 3 fundamental principles in view, these being to minimize the cost of labor in handling fuel and ashes, to obtain maximum combustion efficiency and operate the furnace without smoke. To obtain these ideal conditions, a number of features have been adopted in the design of the grate which are peculiar to this apparatus.

The grate bar, which is in fact a link in the chain, is of a peculiar construction. As shown in the illustration, air passages to the surface of the grate are at

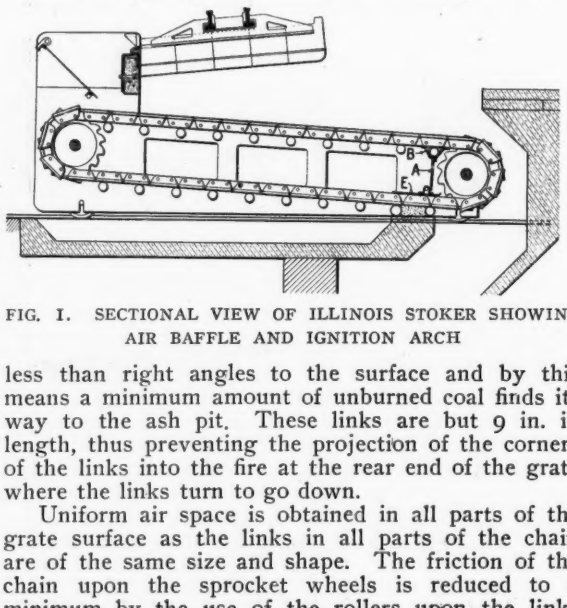


FIG. 1. SECTIONAL VIEW OF ILLINOIS STOKER SHOWING AIR BAFFLE AND IGNITION ARCH

less than right angles to the surface and by this means a minimum amount of unburned coal finds its way to the ash pit. These links are but 9 in. in length, thus preventing the projection of the corners of the links into the fire at the rear end of the grate where the links turn to go down.

Uniform air space is obtained in all parts of the grate surface as the links in all parts of the chain are of the same size and shape. The friction of the chain upon the sprocket wheels is reduced to a minimum by the use of the rollers upon the links which engage with the sprocket wheels. The sprocket wheels upon the rear shaft are loose but held from slipping sideways by collars on the shaft. This pro-

vision is made in order that if, for any reason, the rear shaft fails to turn the sprockets will rotate upon it and thus eliminate the danger of breaking the chain or twisting the shaft.

The slack of the chain is taken up at the front end of the stoker by means of a takeup which is placed at the front outside of the furnace. The chain is supported every 12 in. on both forward and return travel by supports which extend across the stoker and hold the sides at proper distances, every second one being a compression member. An enclosed worm gear supplied with a continuous lubrication is used to operate the chain. The speed of travel of the chain grate is regulated by controlling the number of teeth

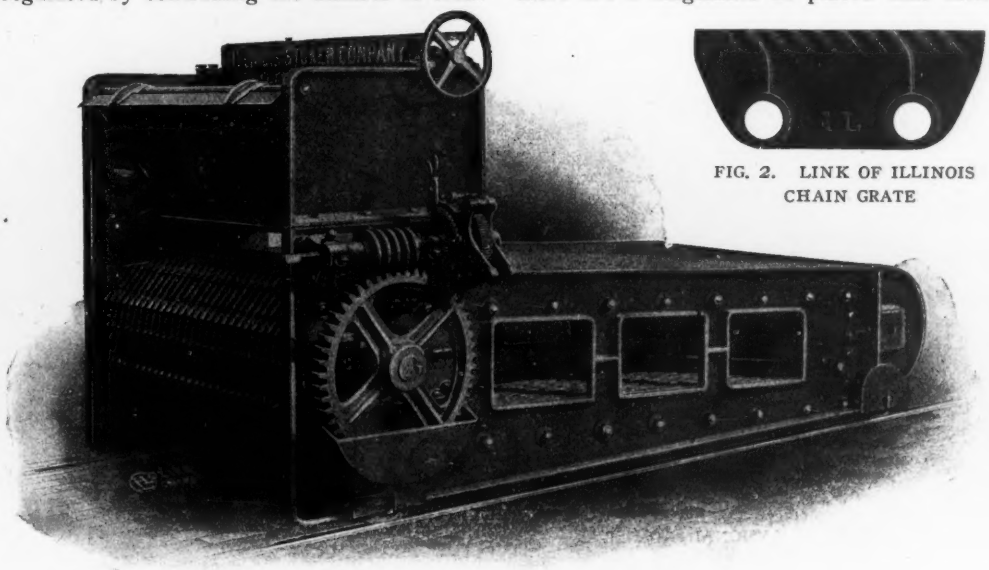


FIG. 3. ILLINOIS CHAIN GRATE STOKER

on the ratchet wheel that the pawl engages at each stroke. This is done by moving the hand lever forward or backward. By this means a variation in the grate travel of from 1 in. to 5 in. per minute can readily be obtained.

Coal is supplied to the stoker through the hopper placed in front of the boiler from which it is fed upon the grate through a feed gate which regulates the depth of the fuel bed up to a depth of 12 in. This gate is adjusted by means of the hand wheel shown in the illustration and is protected from the heat of the furnace by fire brick lining.

The ignition arch employed in this furnace is of the flat self-supporting type giving uniform ignition across the entire furnace width. This arch is supported by 2 cast iron beams placed off centers which rest on the side walls of the setting thus eliminating any thrust on the side walls. The tile used in this arch are so designed that they can be renewed quickly at small cost.

After the coal has been completely burned the ash passes over the rear end of the grate and falls into the ash pit. A special arrangement has been provided to keep the air from passing around the end of the grate into the combustion chamber. This is done by means of the air baffle A, together with the attachments B and E, and also the peculiar shape of the grate bars. This construction eliminates the use of the water back, but it is supplied in connection with the grate if desired.

In construction, this grate is made extremely heavy, being braced with stays every 12 in. along the top and bottom, supplemented by diagnal rods which make the grate thoroughly substantial. The entire stoker is mounted upon wheels which run on tracks and make it possible to move the stoker from the boiler setting with the least amount of labor.

THE INTERNATIONAL STOKER

The International Stoker Co., Baltimore, Md.

In this stoker the principle of coking is combined with that of the double inclined grate. In the furnace there are 2 magazines so placed that each one will take care of half the width of the furnace. On the sides of these magazines are the grates, which incline downward toward the center and sides of the furnace. At the front end of each magazine is a hopper to which the coal is fed, either by the fireman or by the chutes leading from the bottoms of coal-bins overhead.

FIG. 2. LINK OF ILLINOIS CHAIN GRATE

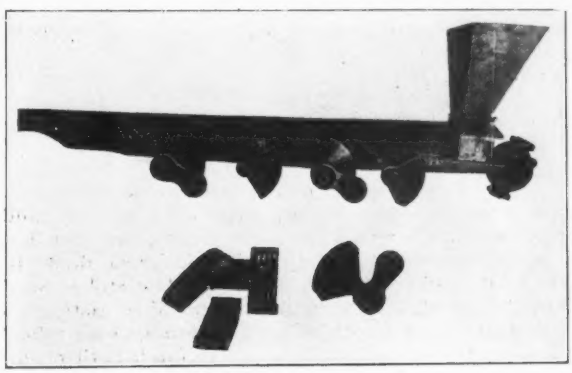


FIG. 1.—DETAILS OF INTERNATIONAL STOKER

After the coal is placed in the hoppers it is conveyed into the furnace by what are termed conveyors, the parts of which are shown in Fig. 1, the number depending on the depth of the furnace. These conveyors oscillate about a shaft and work alternately, that is, while one is moving up the other is moving

down. By this action the coal drops or fills in front of the conveyors, and as it reaches its extreme forward position, the second conveyor has reached its extreme lower position and takes the coal that has been conveyed forward by the first conveyer and pushes it up the inclining bottom, known as uptakes, which is then partly thrown over the top to be conveyed by a third conveyor and partly pushed to the fire surface.

The process is repeated by the succeeding conveyors. The conveyors are set so that each succeeding one will take a certain proportion of the coal conveyed to it, leaving the remainder to be pushed to the fire surface. This proportion is constant, no matter how fast or how slow the coal is fed. The portion of coal in the course of being pushed to the fire surface is gradually heated and ignited and thereby formed into coke.

The process being continuous, the formed coke is heaped up above the magazine which, partly through gravity and partly through the action of the conveyors, falls to the inclining grates on the sides and is gradually worked to the center and sides of the furnace. The continuous oscillating motion of the conveyors, gives a breathing motion to the fire bed, keeping it open and free for the circulation of air and doing away with the slice bar.

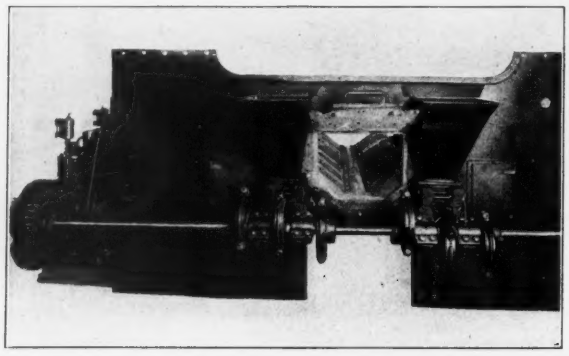


FIG. 2.—THE INTERNATIONAL STOKER

In the center and sides of the furnace, the grates are made to shake at the will of the fireman. The conveyors of each magazine are operated by arms and rods connected to 2 eccentrics attached to the shaft in front of boiler, known as stoker shaft. This shaft is driven by an engine placed at right angles to it, at the side of the boiler, connected through a reducing worm and spur gears.

THE CROSBY SYSTEM OF BURNING COAL

International Stoker Co., Chicago, Ill.

In the Crosby system each machine is a complete unit in itself, steam motor, governor, feeding and spreading mechanism, all in one. The ordinary fire door is replaced by a specially designed door, to which the stoker head is attached. The stoker head consists essentially of the double chamber casting, in one chamber of which a small steam turbine wheel runs, carried by a shaft running through both chambers. In the other chamber the blades revolve that throw the fuel. The shaft carries on one end a fly-ball mechanism which controls the speed of the engine. The governor is entirely enclosed and runs in splash lubrication which also oils the bearing which carries that end of the shaft.

On the other end of the shaft there is a worm reducing gear and cam mechanism, running in oil in an oil-tight case, and furnishing the movement for the spreading device and the feed control. The bearing carrying this end of the shaft is oiled from the gear case.

The turbine engine which supplies the power is a simple affair and is carried on a shaft which runs on ball bearings. It has no valve parts or connections, and no moving parts whatever, aside from the revolving disk, having 1/16 in. clearance all around it. The spreading device lays the fuel in alternate rows, and is similar to the alternate method of hand firing except that it is subdivided and carried out mechanically, continuously, and with the fire door shut.

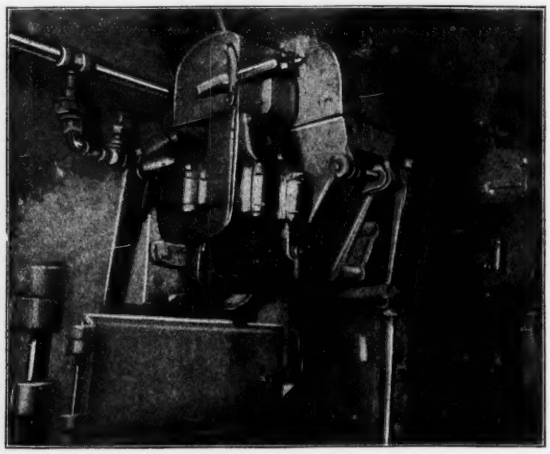


FIG. 1.—THE CROSBY STOKER IN OPERATING POSITION

Feed control is secured by a chain and rakers in the bottom of the hoppers which are placed directly above the stokers and attached to the boiler front.

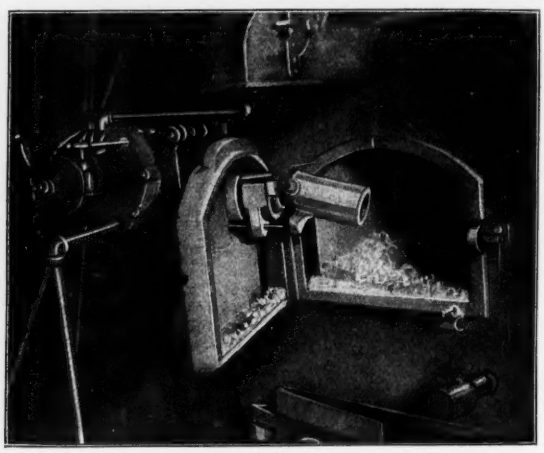


FIG. 2.—CROSBY STOKER WITH FIRE DOOR OPEN

This chain is actuated by a ratchet movement controlled by a small lever by means of which the rate of chain travel is varied to suit the quantity of coal required.

CROWE CHAIN GRATE STOKER

The Ironworks Co., Jersey City, N. J.

These automatic chain grate stokers are machines operated by a worm and gear which revolves a shaft over which pass endless chains carrying transverse grate bars, which carry fuel from a hopper through

the furnace chamber and automatically discharge the remaining ash over a bridge upon a dump plate, returning under the fire over rollers which remove slag, to repeat the work. All this is set permanently but adjustably, with flexibility where needed. All construction is of structural steel except bridge, walls and fire brick arch.

Breaks in the fire bed are prevented by a raised bridge over which ash passes, giving back pressure against the burning fuel.

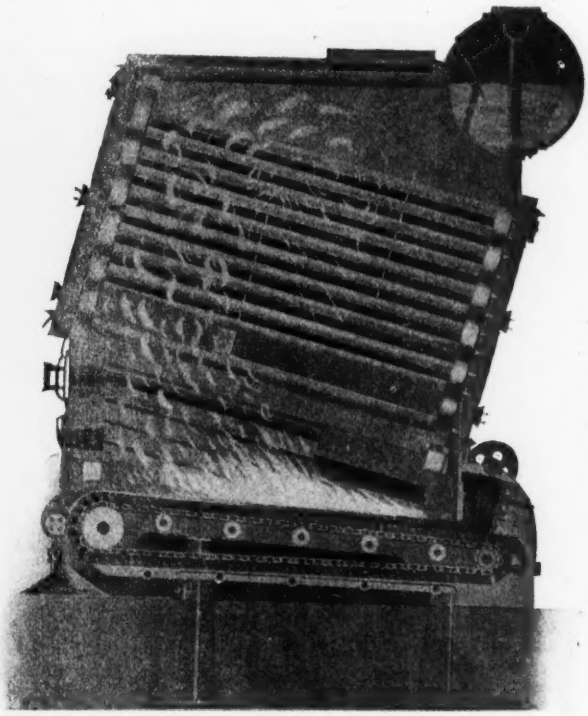


FIG. 1.—CROWE CHAIN GRATE STOKER ADAPTED TO MARINE TYPE WATER TUBE BOILER

Arches of fire brick mounted over the front end of the stoker, heated to high temperature, drive out all volatile carbon from the fuel, which passes over the fire in the combustion chamber and is consumed thoroughly, giving additional heat of gas flames above the fire. All remaining combustible is consumed before reaching the rear of the stoker, making a minimum of ash.

Repairs are easily made, any section injured being easily replaced. In case grate bars are found defective, they may be replaced in a few minutes as they reach the front of the stoker without interfering with the fire. Stokers may be hand fired if necessity arises, and there is no need to pull the fire to repair grates.

As all ash and slag are automatically discharged on the dump plate, cleaning of the fire is unnecessary; from there the ash is discharged into the ash-pit periodically by a hand operated rod.

Oscillation, agitation and the wavy motion of the fire bed, to prevent clinker and keep draft free, is obtained by an irregular motion of the grate bars as the grate chains pass over carrying wheels. Depth of fire bed is regulated by the size of opening from the hopper.

These stokers are designed, by slight changes in construction, to use bituminous or anthracite coal, or mixture.

The stoker is designed for natural or forced draft, a hood being provided to the stoker for the latter to complete enclosure of the stoker.

The Ironworks Co. manufactures these stokers under a license from Paul L. Crowe.

LACLEDE CHRISTY CHAIN GRATE STOKER

Laclede Christy Clay Products Co., St. Louis, Mo.

The grate of this stoker is an endless chain, consisting of a series of narrow links, all of the same design. Between each 2 links is placed a cast-iron roller. The width of the roller regulates the air space between the links, and is made to suit the different grades of coal. Any link can be replaced easily without removing the stoker. The driving shaft is mounted on a

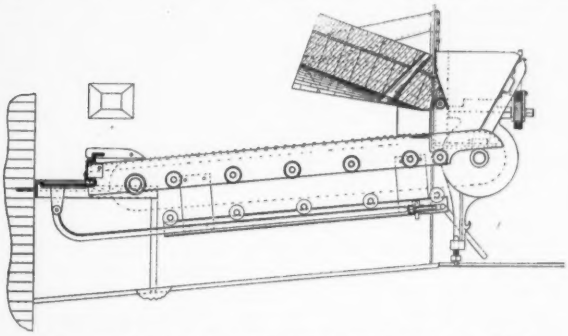


FIG. 3.—SECTIONAL VIEW OF CROWE CHAIN GRATE

movable box and provided with a tension bolt, and any slack of chain may be taken up while the stoker is in operation.

A unique feature of the Laclede Christy chain grate is the roller and dumping attachment, which consists of a series of corrugated cast iron rollers mounted loosely on a shaft, and cast-iron dumping plates built in sections, and can be operated by levers either from the front or side of boiler. This attachment does the work of the overhanging bridge wall or water back, and shuts off the excess of air giving a flue gas high in CO_2. Unconsumed coal will be retained by the rol-

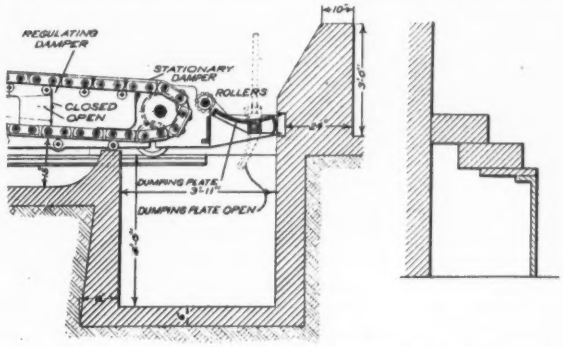


FIG. 1.—AIR BAFFLE SYSTEM OF LACLEDE-CHRISTY STOKER AND DETAIL OF SIDE WALL

lers until burned out, giving an ash low in carbon and assuring fuel economy.

The flat ignition arch is carried on an I beam, which has a bearing on the side walls of the furnace. On to this I beam are bolted cast iron brackets at proper distances from center to center to allow for the hanging of firebrick tile between each set of brackets.

In order to prevent air from going up through the end of the grate where nothing but ashes are found, a stationary damper is provided as indicated in accompanying illustration. Another damper is placed to the front of the stationary damper and is called a regulating damper. This damper is used to regulate the amount of air passing through the grate and into the combustion chamber, its chief object being to enable the operator to carry a short fire when the load is light, without the loss of fuel economy. This damper further baffles and distributes the air more evenly when the full grate surface is being used, and shuts off the air entirely from the rear end of grate where there are no live coals when working small loads.

There is provided at the rear of grate a set of rollers and a reflecting plate; the fine ashes pass between the end of the grate and the rollers and drop into an ash pit. The larger pieces of ash and clinker pass over the rollers, lodging on the reflecting plate and at certain periods of the day this plate is dumped, throwing the ash and clinker into an ash pit.

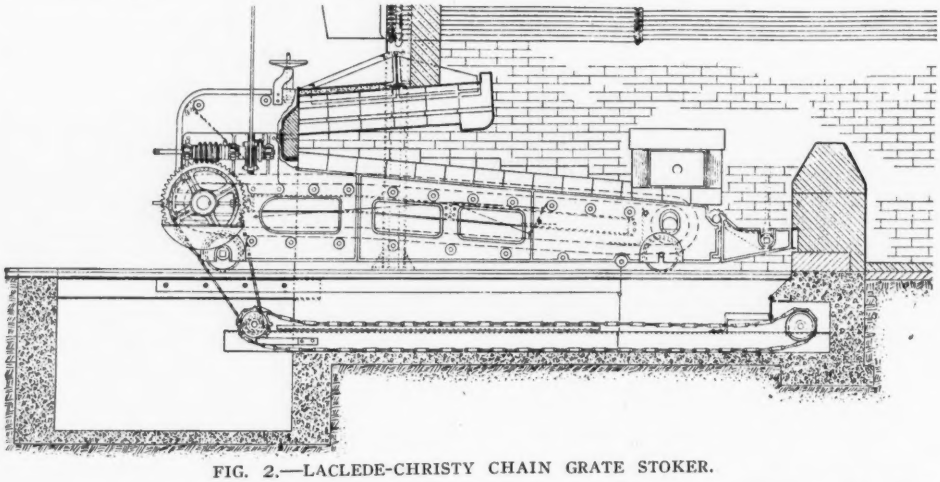


FIG. 2.—LACLEDE-CHRISTY CHAIN GRATE STOKER.

THE LEE PRINCIPLE OF COMPLETE COMBUSTION

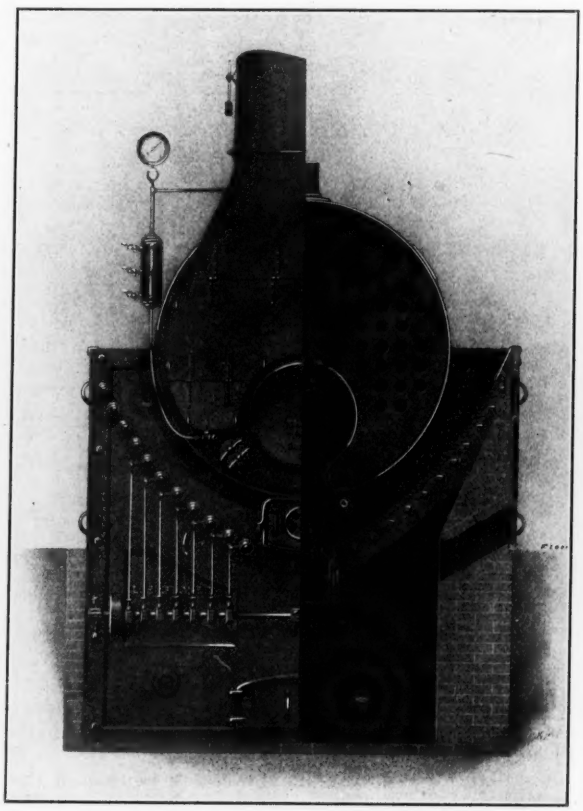
The Lee Smokeless Combustion Co., New York.

The stoker of this system consists of a side grate, arranged on the arc of a circle and conforming nearly to the outline of the lower half of boiler shell, and also a semi-flat grate of the interlocking variety immediately beneath the boiler. The units of which the side grates are composed, are bars 14 or 16 in. in length or combination thereof and of the cross-section shown in the illustration; that is 4 leaves with spaces between for the admission of air.

The grate bars are mounted in series, in units sufficient to create a suitable area of grate, on a square bearing bar running the length of the furnace and projecting through the furnace front, so that by means of a wrench, or automatically, as indicated at the left of figure, the bars may be given a slight movement which accelerates the movement of the coal toward the bottom or sifting grate.

There is provision for admittance of air at 2 points on the sides of the furnace, and also through the fuel at the top. The air passing through the orifices in the entire circle of the grates, being less than the volume required by the furnace, the balance enters downwardly through the fuel and through the upper air orifices, when the fuel is fine or compact, drawing the fire up through the columns of fuel; this being an application of the principle that fire will burn against the draft, while smoke and gases must travel with the draft.

Dampers are provided as shown, to regulate and control the action of the furnace. When the air admission is limited the power of the furnace is limited. In other words, horsepower development in a steam making plant can be regulated to almost any desired unit from the maximum, when all the dampers



SECTIONAL VIEW OF THE LEE FURNACE

are open, to the minimum when all are closed. With this arrangement the coal is coked in the upper part of the side grates, and the volatile gases driven off are

carried by the down draft through a bed of incandescent fuel, into which, through the orifices in the entire circle of the grates, an adequate supply of air enters, becomes highly heated, and with which the products become thoroughly mixed before they can enter the boilers.

The boiler itself is simply a modification of the continental boiler, containing a 27 in. corrugated flue to carry the gases to the rear, and a few more tubes, by reason of the small diameter of corrugated furnace, than is usual in this type of boiler. The gases enter the corrugated flue through a narrow neck which connects the outer shell of the boiler with the flue, of the same length as the grate and of sufficient width to give substantially the cross-sectional area of the tubes, and wind around the large flue to the rear of the boiler and pass out through the tubes to the stack.

The boiler is set on the floor line, with a pit in front about 2.5 ft. deep to accommodate the boiler front, giving room for the ash pit and space for the engine tender or fireman to give the side grates a slight upward movement regulating the feed of the coal, also to remove the ashes from the bottom doors.

McKENZIE STOKERS

McKenzie Furnace Co., Chicago, Ill.

The Traveling Grate Stoker

This stoker as designed, and the entire combination is properly proportioned for the purpose of burning the average coals. It is made with what is termed a double acting operating mechanism, giving a continuous travel to the grate surface which does not permit it to stand still any part of the time; the speed of the grate is controlled by the operating mechanism to suit the conditions under which the machine is working.

The double acting mechanism in connection with this machine consists of 2 ratchets operated by 2 eccentrics set at opposite centers, with the eccentric rods passing through an internal tube, which is supplied with a tension spring. This tension spring being set to suit the conditions under which the machine is working will release itself and notify the operator should any accident occur to the machine. The 2 eccentrics are attached to a shaft which is driven by an electric motor of 1.5 hp. and are connected to ratchet arms operating the small shaft, which in turn operates the large worm wheel driving the entire mechanism.

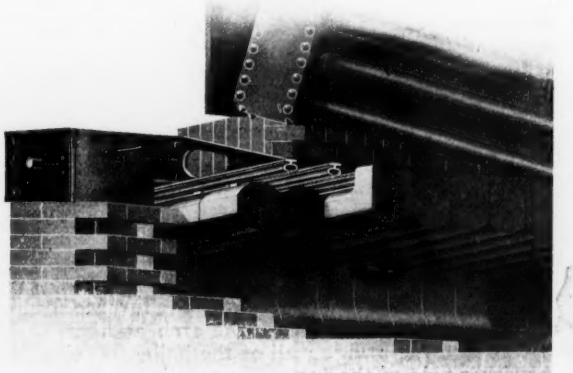


FIG. 2. MCKENZIE IGNITING ARCH

The grate in this machine is of what is known as a truss form, and is divided into a number of parts the full width of the machine, having the entire grate surface detachable and fastened to the lower bar in small sections instead of being cast in 1 long bar; this is for the purpose of removing a section should any part of the grate bar become damaged. These sections bed on the surface of the bottom bar, being fastened in place by bolts which pass through the bottom bar, and are screwed into nuts that are inserted in the sides of the small sections. The top surface of the bar and the bottoms of the small parts are carefully milled so that in placing the bar in the machine it is perfectly straight, and is as compact as if cast on one piece. The ends of each bar are milled on both sides and the bottom where it sets into the large driving links on the machine, and are drilled from side to side for the purpose of bolting into the links. In case of repairs to this bar every section fits perfectly and is reversible, because all parts are milled in jigs and are turned out in exact duplicates.

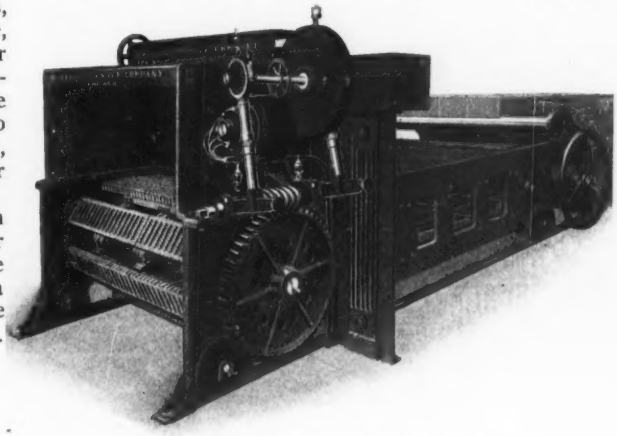


FIG. 1. MCKENZIE TRAVELING GRATE STOKER

The heavy driving chains conveying the grate bars, are adjustable at the front end by a pillar block and are mounted on horizontal tracks perfectly milled and set in such a manner that the grate surface is always perfectly level both bottom and top, thus reducing the friction to not over 0.25 hp. on a 500 hp. machine, and is so arranged that in case of necessity the stoker can be driven by an engine or otherwise.

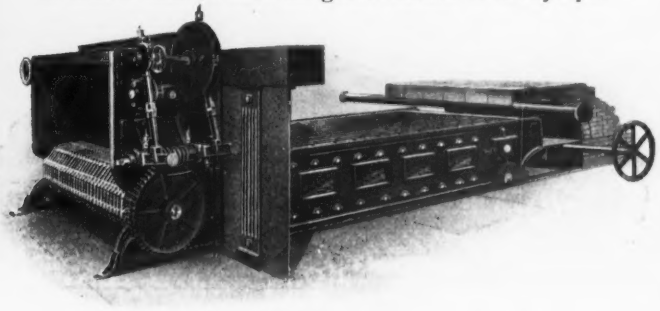


FIG. 4. MCKENZIE CHAIN GRATE STOKER

The machine is equipped with a clinker apron and horizontal dump grate which forms an ash receiver at the rear end of the machine, preventing an excess of air and retaining all unconsumed coal that may pass over the rear, giving the heating surface the benefit of the total heat units liberated from the coal.

The face of the bridge-wall is equipped with a skeleton iron construction combined with the circulating tube, making it practically indestructible. The sides of this machine are equipped with an air seal for preventing an excess air when in the boiler setting. The coal hopper and its coal gate, and the entire mechanism for operating it to adjust the thickness of the fire are simple and durable.

This machine is also equipped with a flat suspended igniting arch, so constructed that it can be adapted to any width of boiler and any depth of arch. The illustration shows the general construction of this arch and its location under a boiler, as well as that of the tile which covers the hopper grate in connection with the stoker when attached to a boiler. The efficiency derived from this arch is due to the fact that equal distribution of the gases over the entire heating surface of the boiler is secured.

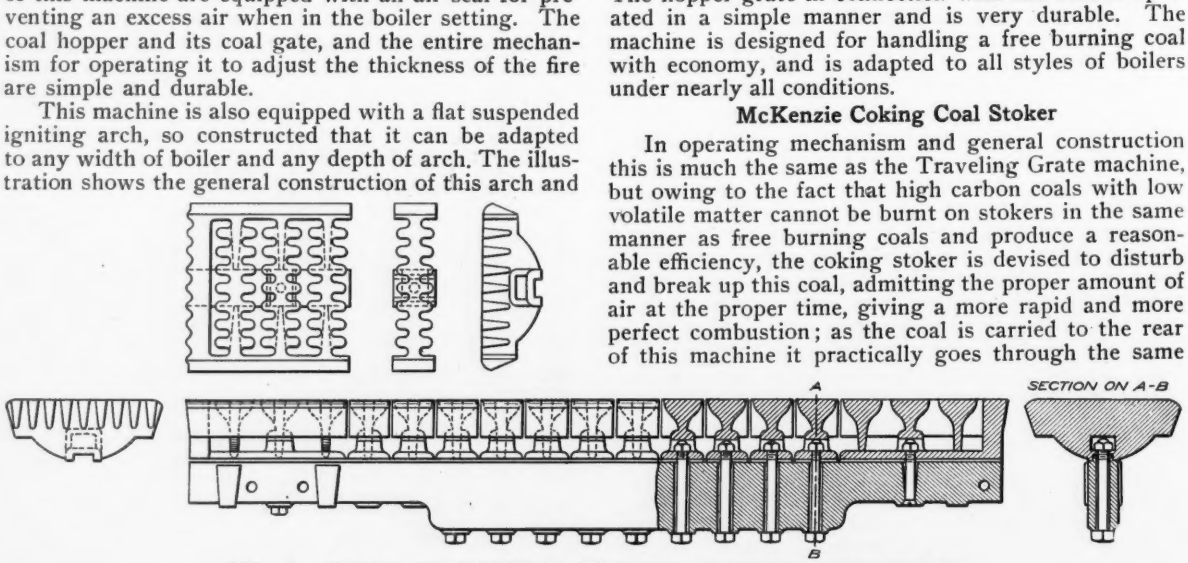


FIG. 3. DETAILS OF MCKENZIE SECTIONAL TRAVELING GRATE STOKER

McKenzie Chain Grate Stoker

This machine is termed a chain grate stoker from the fact that the coal is burned on a chain which forms the grate surface, and the general mechanical construction is arranged to be as convenient as possible when under a boiler. It is equipped with a clinker apron and horizontal dump grate at the rear, as well as the circulating tube in the bridge wall; it is also equipped with a double acting operating mechanism, motor driven, the same as that used on the Traveling Grate stokers, and is so arranged that it is adjustable at the 4 corners of the machine, the rear end adjustment being used when the machine is originally installed. All other adjustments are taken up from the front, and should it be necessary to remove the front shaft of this machine it can be done by removing the front sprocket wheels, pillar blocks, worm wheel and the entire front end of the machine instead of taking anything apart.

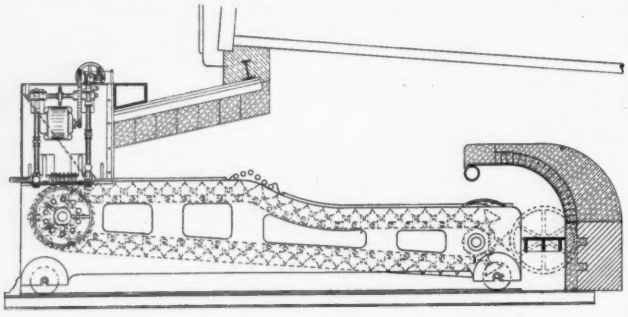


FIG. 5. MCKENZIE COKING COAL STOKER

The operating mechanism is of a double eccentric type, set at opposite centers, giving the machine a continuous travel. This machine is equipped with either the curved or suspended igniting arch; independent air seals on the sides are furnished when it is installed. The hopper grate in connection with the coal is operated in a simple manner and is very durable. The machine is designed for handling a free burning coal with economy, and is adapted to all styles of boilers under nearly all conditions.

McKenzie Coking Coal Stoker

In operating mechanism and general construction this is much the same as the Traveling Grate machine, but owing to the fact that high carbon coals with low volatile matter cannot be burnt on stokers in the same manner as free burning coals and produce a reasonable efficiency, the coking stoker is devised to disturb and break up this coal, admitting the proper amount of air at the proper time, giving a more rapid and more perfect combustion; as the coal is carried to the rear of this machine it practically goes through the same process the second time previous to the ash and unconsumed particles of coal passing into the ash receiver.

The special feature is that the grate surface has 2 levels, with the mechanical breaking device at a given point as shown on the cut, breaking up the coal and throwing it on the lower grate surface. On the higher grate level the coal is received and coked.

THE MURPHY AUTOMATIC SMOKELESS FURNACE

The Murphy Iron Works, Detroit, Mich.

The design of the Murphy furnace was developed in recognition of certain fixed principles. Subsequent changes and improvements have greatly increased its efficiency, and more particularly its durability, reducing the cost of repairs to a minimum, but they have left unchanged all of the essentials of the original design.

The action of the Murphy stoker is such that mingled air and gas pass downward over the surface of the coal toward the center of the furnace, and there meeting a circulating current of air and gas from the opposite side of the fire, the combustion is thoroughly and speedily effected.

The inclined fires on both sides of the furnace form 2 of the incandescent surfaces, the arch another, the front wall and the bridge wall of the boiler, others.

At either side of the furnace, extending from front to rear, is a coal magazine into which the coal may be introduced either mechanically from conveyors or by hand. At the bottom of this magazine is the coking plate, against which the inclined grates rest at their upper ends. The stoker boxes, operated by segment gear shaft and racks, push the coal out over the coking plate and on to the grates.

The grates are made in pairs, one fixed, the other movable. The movable grates, pinioned at their upper ends, are moved by a rocker bar at their lower ends, alternately above and below the surface of the stationary grates. The stationary grates rest upon the grate bearer which also contains the clinker or ash grinder. This grate bearer is cast hollow and receives the ex-

haust steam from the stoker engine. This steam escapes through small openings at regular intervals on either side of the clinker grinder and lower ends of the grates, to soften the clinker and so assist the cleaning process. The clinker grinder is also cast hollow, and is connected by a 2-in. pipe with the smoke flue. Through it a volume of cold air passes constantly to prevent its destruction by the heat.

Just over the coking plate is the arch plate from which a fire brick arch is sprung over the entire furnace. Upon this arch plate are cast numerous ribs, about an inch apart, forming a series of air ducts immediately over the coking plate. All such air is utilized in the furnace proper being delivered to gas distilled from the coal at a point where a sudden increase in temperature is desirable.

In this connection it may be said that a special air cooled fire door is employed. The liner in this door is cooled by a current of air which passes in contact with a number of ribs placed on its side nearest the fire door. Provision for a variable expansion of the door and liner is made and the liner, the door and the door handle are held together by a single bolt.

Thus any furnace may be thrown into commission or disconnected without stopping the engine or interferring with the operation of the remainder of the plant; and it can be successfully operated by hand, the fuel fed and the ash removed in the same manner as when controlled by the engine. This prevents any possibility of the furnace or boiler being thrown out of commission by the breaking of any portion of the actuating mechanism.

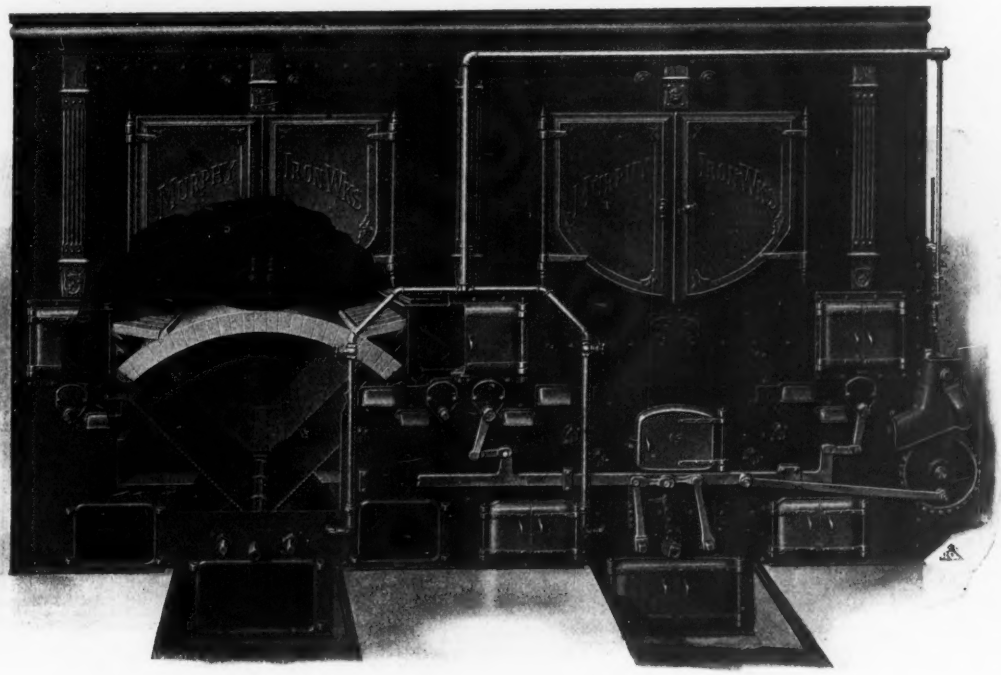
As the coal leaves the magazine it rests upon the coking plate. The volatile gases are driven off and mixed with the heated air admitted through the air ducts in the arch plate, thus insuring complete combustion. The coal, having been coked, travels slowly down the inclined grates toward the clinker grinder. receiving air in the ordinary way through the grates to complete the burning process.

The speed at which the stoker boxes push the coal on the grates can easily be regulated to conform to the duty required. Likewise the clinker grinder can be turned slower or faster according to the amount of ash in the coal.

THE SWIFT STOKER

The Swift Fuel Company, Chicago, Ill.

Automatic and continuous feeding of coal is accomplished by the Swift stoker, which is a self-contained machine, bolted to a frame casting, which hangs upon the front of the boiler in place of the regular fire door. The stoker mechanism proper covers but a strip across the upper part of the boiler fire-door opening, and a fire door, with lining, is fitted in the supporting frame of the machine, giving access to the furnace at all times for slicing, removal of clinkers, etc. The stoker as a whole may be swung back from the fire-door opening the same as a regular fire-door, as shown by the illustration.



THE MURPHY AUTOMATIC FURNACE

Several sizes of this stoker are designed to meet the various conditions of application. By reference to the illustrations it will be seen that the fuel is thrown into a hopper which has a capacity for about 300 lb., and is placed above the machine. From here it is fed by means of a berm plate and pusher plate to rapidly revolving spreaders which throw it on to the grates, giving an even continuous feed with a uniform distribution of fuel over the entire grate area.

It will be noted that the spreaders are fastened upon pins, and are thus given a flexibility, which allows them to swing back in case slate or other rock is thrown into the hopper, thus obviating the danger of breaking the spreader arm. The rapidly revolving shaft upon which the spreader arms are attached

throws the spreaders to their outermost position by centrifugal force. By this arrangement it is possible to handle large lumps, the spreaders breaking and throwing the coal on the grates, although designed for screenings, slack and the commercial sizes.

The berm and pusher plates are moved by 2 levers acting in unison and actuated by a revolving cam on the side of the machine. Variation of the feed is obtained by means of a block on a graduated scale, the position of this block determining the movement of the berm and pusher plates, and hence the amount of fuel fed to the spreaders.

FIG. I.—THE SWIFT STOKER ATTACHED TO BOILER

The spreaders are heavy pieces of cast steel, of helical shape, so as to throw the fuel in a direction other than at right angles to the face of the machine. There are several of these spreaders so arranged on the shaft that adjacent spreaders throw the fuel in different directions, thus accomplishing a uniform spread. The speed of the spreaders varies for different depths of grates and is adjustable.

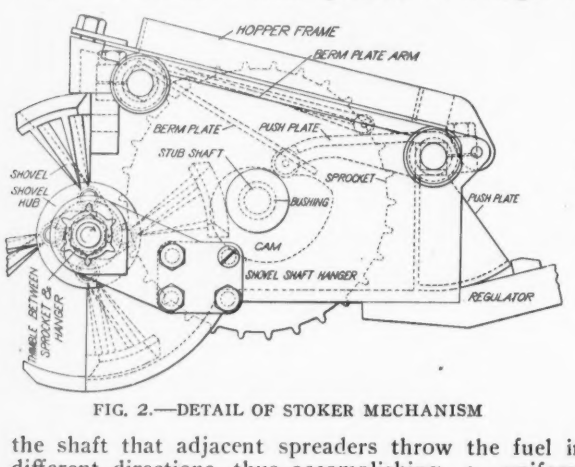


FIG. 2.—DETAIL OF STOKER MECHANISM

For operating the stoker a shaft is run along the front of the boiler, upon which chain wheels are placed which carry endless chains to the wheels on the stoker. A small steam engine or motor is usually employed for driving the line shaft.

THE JONES UNDERFEED STOKER

Underfeed Stoker Co. of America, Chicago, Ill.

This stoker, invented by Evan William Jones, of Portland, Ore., and patented in 1889, was the first mechanical stoker to apply the principle of underfeed firing in practicable form. Since the stoker first was designed by Mr. Jones as a wood burner for the purpose of utilizing green fir wood to advantage under steam boilers, changes have taken place in the details of construction, but the basic principle of underfeed firing, then applied to dry the green wood by firing it beneath the blazing flames of the furnace and now applied to coke the green coal by introducing it beneath a burning bed of fuel, has remained unchanged.

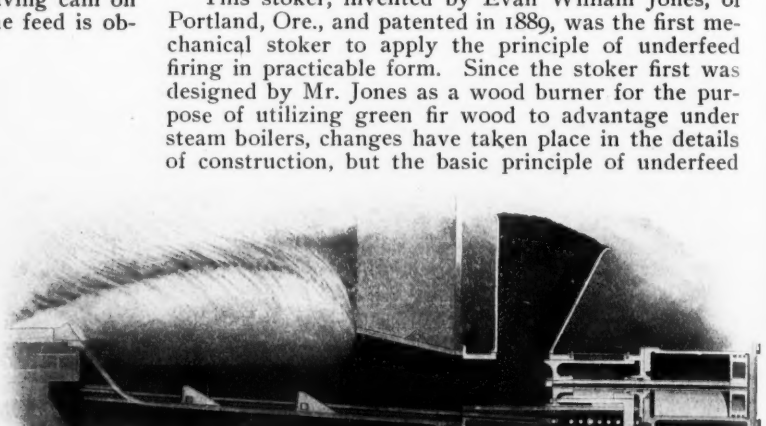


FIG. I.—SECTIONAL VIEW OF JONES UNDERFEED STOKER

Thus the theory of underfeed firing has been successfully adapted in practical form to commercial purposes for the utilization of bituminous coal, and this, as shown by recent experience, necessarily is not confined to stationary plants but also in marine service.

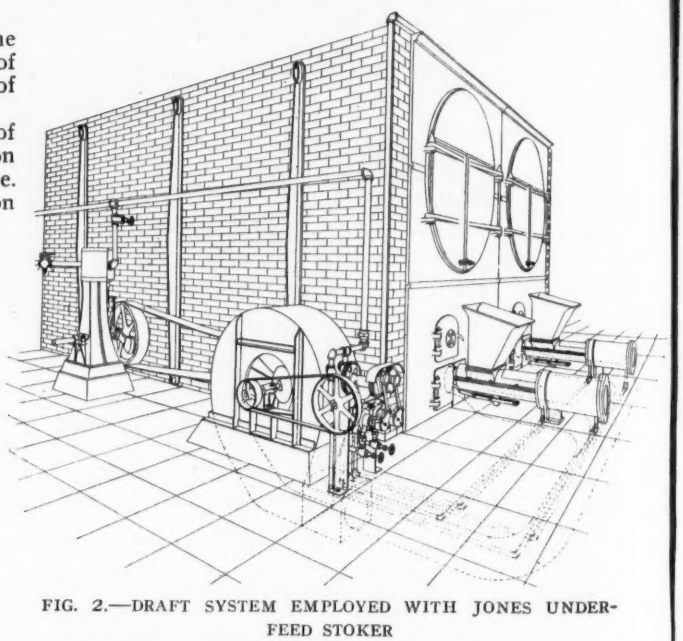


FIG. 2.—DRAFT SYSTEM EMPLOYED WITH JONES UNDERFEED STOKER

In the Jones stoker there are no moving parts in the furnace exposed to the direct action of the intense heat which it is a mechanical stoker's prime mission to generate, and this absence of complicated parts, either within or without the furnace, means low cost for

maintenance. The standard size of this stoker is adaptable to all types of boilers in general use; the need of different sizes for the varying furnace widths of different boiler units being entirely obviated by providing the proper width of dead plates to extend from the retort to the side walls.

Simple construction in all details makes the installation of the stoker easy and little change of existing conditions is required where boilers already are in service. Material and labor necessary to make the installation will amount to about the same as for setting common grates, no special tile or fire brick being required.

Inside of the furnace is the retort, with an auxiliary ram in its bottom; the tuyere blocks, through which air is delivered to the fuel bed, are secured to the upper edges of the retort; and the solid cast-iron dead plates extend from each edge of the retort to the furnace side-walls. Outside of the furnace the stoker consists of the hopper, holding the supply of coal, and the steam cylinder and ram case, which houses the ram by which the fuel, descending through the hopper, is thrust into the furnace.

In addition, the equipment comprises a fan blower to furnish the air for combustion; the engine to drive the blower, either belted or direct connected thereto; the air piping to conduct the air from the blower to the boiler furnaces, run either overhead or underground as circumstances dictate; and valves or blast gates in the branch air ducts for controlling volume and flow.

Proper proportioning of the fuel supply and the air is absolutely necessary if perfect combustion is to be had. This is a principle of physics and chemically applied in the Jones underfeed system, but the system also goes a step further in making the steam pressure automatically proportion the fuel and the air to each other for varying loads. To accomplish this, the engine driving the blower is equipped with a regulating valve, which, as the steam pressure rises above a certain point, throttles the supply of steam, thereby slowing down the engine and the speed of the blower, and consequently diminishing the output of air and fuel, or vice-versa should the steam pressure fall.

On a stand located in close proximity to the blower or at a distance if circumstances require, is a bank of rotary disk valves, depending in number on the number of stokers installed, since each valve controls the admission of steam to a stoker cylinder. These valves are driven by a belt connected to the blower, the relative size of the 2 pulleys being calculated so as to maintain the proper proportions between the output of the blower and the rate of fuel feed. The immediate effect is to diminish the amount of air and to decrease the quantity of fuel admitted to the furnaces if the steam pressure rises, and on the contrary to increase the amount of air and to increase the quantity of fuel if the steam pressure falls. Thus is secured a correct proportioning of fuel and air, producing a clean and perfect combustion, and eliminating smoke, while at the same time steam production and consequent burning of fuel are limited to actual requirements.

As its name indicates, this stoker introduces the coal under the fuel bed in the furnace, as shown in the sectional view, instead of depositing it on the fire. Descending through the hopper to a position immediately in front of the ram, the coal is carried into the retort by the forward movement of the ram, the green coal entering the furnace beneath the fire line and being raised by successive charges to the point where its gases and volatile matter are released by the incandescent fuel above. At this stage, the gases are mingled with the air driven through the tuyeres and, in making their escape through the heavy bed of burning fuel, are consumed and thereby turned into heat.

By this method of firing, the use of cheap grades of coal is made possible and there can be no waste because, when once introduced into the furnace, the fuel must remain there until burned. Every particle of heat value which the coal contains is extracted and applied to the heating surface and automatic regulation makes it certain that only such quantity of fuel is burned as is necessary to meet requirements.

THE WESTINGHOUSE NEW MODEL RONEY MECHANICAL STOKER

The Westinghouse Machine Co., East Pittsburg, Pa.

Considering the general type of this furnace, the grate is stepped, inclined at just sufficient angle to insure an easy downward movement, aided by the rocking motion, without any tendency for the fire to tumble. A horizontal shaft, extending across the front of the stokers, and driven by a small single-acting, enclosed type engine, supplies through an eccentric, a reciprocating motion necessary to rock the grate and advance the pusher shown at the top of the incline, just outside the entrance to the arch. While the throw of the eccentric is fixed, the actual motion of the pusher and grates may be adjusted at any time by means of the hand wheel and cap sheath nut shown on the outside of the stoker, thus working at a constant rate of feed until again adjusted.

INTERIOR VIEW OF THE RONEY STOKER

The reverberatory arch extends out far enough to insure that all volatiles are carried down into the hottest part of the furnace and there completely burned. Incidentally, it will be noted that with the horizontal or semihorizontal tubed boiler, the distance between grate and tube surface rapidly increases as the coal advances. This is a particularly good feature, and makes it easier to provide the furnace depth necessary in burning long-flame coals.

The grate unit of this stoker consists of a web hung in trunnions between side and center bearers or supports. These webs carry numerous vertical grate bar tops or fire-tops mounted in slots along the web and retained by a key-rod, as shown in the illustration. It will be noted that the bearings for these webs are slightly tapered. This makes the bar self-centering in the 2 side bearers with no tendency to excessive

wear on one side or the other. These webs are also made with lugs so as to be interchangeable and avoid rights and lefts in furnace assembling.

An essential feature of this vertical type top is longer life and better air distribution. Near the surface all around the outer edge, the metal is thickened in order to present a greater surface to the fire. And the top is made easily removable so as to facilitate renewal or redistribution over the furnace, placing the best tops at the center and those somewhat worn along the side where the combustion is not so intense. An important improvement in air distribution is shown in the illustration representing an end view of the fire tops in position on the web. Note the uniform space between these tops that is available for constant air admission.

The adjustment of grate motion provided on the Roney stoker makes it possible to vary the effective average air admission according to the rate of burning coal; i. e., to open the grates wider as the rate of combustion increases, and vice versa. On the other hand, the range of fluctuation of effective air admission between the open and closed position, is not so great as to occasion great variation in the length of resulting flame—important in the case of long-flame coals.

With the grates open maximum width, the effective admission area of the entire grate is 36.8 per cent of the projected area of the furnace. At minimum opening of grates, i. e., in their lower position, the effective opening is 24.2 per cent. Taking into account the actual time of opening and closing, the average effective draft area of this type of stoker is 27.4 per cent of the total projected area, as compared with an average of 17.9 per cent with flat horizontal fire tops.

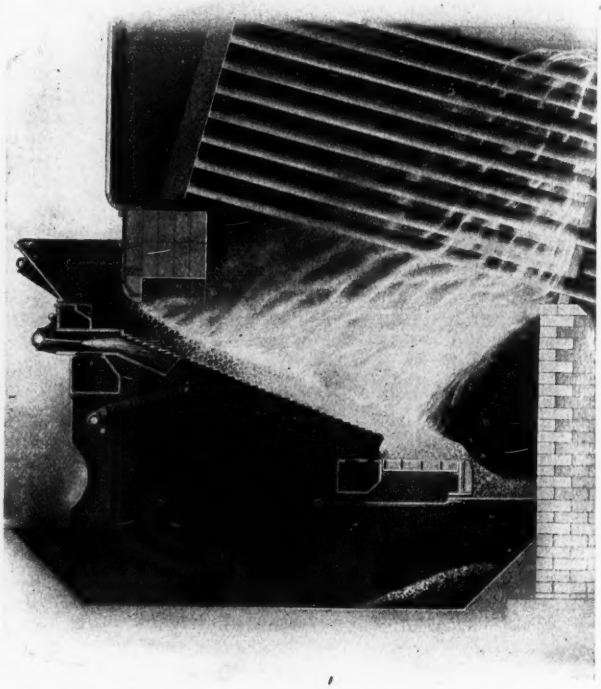
Probably the most important improvement from the standpoint of smoke prevention is in the method of introducing auxiliary air under the stoker arch. Owing to the spring of the arch, air introduced beneath, at the center would tend to follow the crest on its way to the fire; if introduced at the sides, the tendency would be to starve the central part of the fire of air. In the arrangement shown in the illustration the arch air taken in through 2 wind gates at the side of the furnace, is guided by means of baffle walls around and over the arch to the center. Thence, the air spreads uniformly over all parts of the arch, reaching the fire through openings provided between a row of fingered throat pieces and the first course of the arch which these fingers support.

The increased area between arch and roof is made use of to secure the desired uniformity of air distribution underneath. Evidently the air would tend to take the shortest course to the fire, but as the shortest path is the most restricted, the air supply spreads out where the space is greater, with the result that all parts of the fire are equally supplied with air, resulting in more perfect combustion of the volatiles.

All tops, webs, grates and dumping grates are interchangeable. The grates return to their inclined position by their own weight, thus avoiding the necessity of a return thrust from the eccentric rod. The entire series of grates may be held open without disturbing the motion adjustment, by means of a small stop rod engaging the eccentric lever. This enables the fires to be trimmed rapidly at any time, avoiding to a large degree the chilling of the furnace.

In the upper 4 rows of grates, a certain amount of the finer coal would be lost through the slots were standard tops used. This, however, is taken care of by a modified nonsifting top with horizontal side ribs practically closing the space between tops, and preventing sifting while allowing free entrance of air horizontally.

The dumping grate is hinged ⅓ forward with the metal so distributed as to be largely balanced, and hence easy to operate from the floor. Moreover, the concave shape of the grate when dumping, tends automatically to clean the bridge wall, crushing the clinker before it and dumping both front and rear. The guard at the foot of the furnace, in raising, checks the descent of the fuel bed, at the same time dislodging and assisting to break up any clinker bridge showing a tendency to form. Both guard and dumping grate rest in trunnions and may be readily removed without disturbing the side bearers. There are no bolts inside the furnace. Any grate bar can be removed without disturbing the others, and when out of position the key rod can readily be driven out for changing the fire tops without taking the bar out of the furnace.



THE WILKINSON STOKER SHOWING HOLLOW GRATE BARS WITH DRAFT OPENINGS

THE WILKINSON STOKER

Wilkinson Mfg. Co., Bridgeport, Pa.

Crushed or slack coal fed into the hopper of this stoker is mechanically forced down an easy incline under the kindling arch, thence on through various zones of heat and combustion until in the form of partly burned ashes it rests on the ash table until it has been completely burned, and then falls over on to the ash slide.

The incline referred to is provided by heavy hollow grate bars, having an alternate forward motion of about 1.5 in. These bars are of a stepped pattern, and on the rise of each step is an opening of about 0.25 by 2.75 in., which is provided for the passage of air and steam. The surface of the grates exposed to the fire is made of special iron suitable for high temperatures and service. There is introduced into the end of each

grate bar a small steam jet, and all the air or draft for the fire passes through the openings provided for that purpose as mentioned above and shown in the illustration.

There is a constant sawing action of the grate bars causing the fuel to go forward, accompanied by a constant influx of steam and air. The force of the steam jets automatically regulates in proportion to the boiler loads and requirements, thus providing extremely elastic furnace action and a variable load capacity. The primary purpose of the steam jet is to preserve the grate bars from destruction, it also disintegrates the clinkers and enables the use of grate bars set closely together to avoid the waste of fine fuel which is apt to fall into the ash pit.

This stoker accommodates itself very handily to the use of automatic ash handling apparatus and can be used with any type of boiler or furnace now upon the market.

The power for driving this stoker is furnished by small hydraulic motors, 2 being placed on each stoker. For supplying the water used in the motors a small pump and tank are provided, and from the pump the water is carried to each motor, from which it is returned to the tank, thus allowing the continuous use of the water.

MECHANICAL DRAFT

ITS ADVANTAGES AND ITS DETAIL

AS used in power plant practice, mechanical draft may be divided into the forced systems and induced systems, or to use more descriptive terms, the blowing systems and the exhausting systems. In the former, air is forced into the ashpit under pressure and escapes through the fuel bed to the firebox. This permits of comparatively low drafts only, unless careful provision is made for closing the firebox air tight.

Forced Draft

It is obvious that, where pressure is put upon the firebox, gases and flame will be forced into the boiler

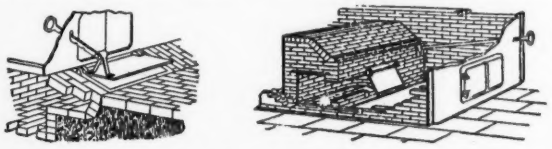


FIG. 1.—DAMPER CONTROL FOR FORCED DRAFT SYSTEMS

room, if there is any opening by which they can escape. All that a forced draft system can do, therefore, is to furnish the draft needed to send the air through the fuel bed, unless, as is sometimes done in marine practice, what is called the closed stoke-hold system be adopted, where the whole boiler room is made air tight and put under pressure. The disadvantages of this system are evident and it would be entirely unsuited for stationary practice.

The other system, induced draft, operates so that gas is drawn from the firebox and thrown into the stack. This may be done either by sending jets of air or steam across the fuel bed, thus inducing strong currents of air through the fuel and forcing the products of combustion through the combustion chamber and boiler into the stack, or it may be done by a fan or blower placed in or near the base of the stack, which draws air through the boiler, combustion chamber, firebox and grate and forces it into the stack.

Steam Jets

Advantage which can be offered by the steam jet system of mechanical draft is that of low first cost only. It is available where forcing of the boilers for a short period at infrequent intervals is necessary, but tests made at the New York Navy Yard in 1890 showed that a steam jet required from 8.3 to 21.2 per cent of the steam made by the boiler to produce the necessary draft. The steam jet used above the grate or the bridge wall to help out in burning the volatile gases can hardly be classed as a mechanical draft device, although it does materially increase the draft.

For stationary practice the standard method for induced draft is the employment of a centrifugal blower which takes its suction from the boiler side of the breeching and discharges into the stack. With such a system a short stack can be used, doing away with the first cost of the brick chimney and its foundations and permitting of close regulation of the draft to suit the load. The only height needed for the stack

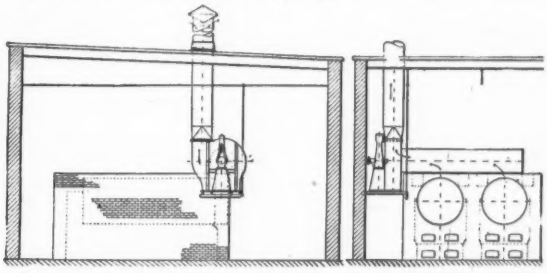


FIG. 2.—ARRANGEMENT OF INDUCED DRAFT SYSTEM

in a mechanical draft system is sufficient to carry away the gases so that they will not be objectionable.

Against this the mechanical draft system has to offer complete control of draft, extremely low first cost of installation as compared with chimney cost, the possibility of enlarging or replacing at moderate

TABLE I.—FORCED DRAFT BLOWER CAPACITY; 6.9 LB. WATER EVAPORATED PER POUND OF COAL

Diam. Wheel Inches	Width at Periphery, Inches	Diam. of Inlet, Inches	Diam. of Outlet Outside, Inches	Speed R. P. M. for 1½ oz. pressure	Capacity Blower cu. ft. per min. Temp. 62 degrees F.	Lbs. Coal per hour 234 cu. ft. air per lb. Coal	H. P. Boiler Capacity 5 lbs. Coal per H.P.hr.	Evaporat'n per hr. 34.5 lbs. Water per H. P.	Brake H.P to drive Blower at Speed
8½	2	4¾	5	3210	386	99	20	690	32
10½	2¾	5⅝	6	2660	576	148	30	1035	48
12	3¼	6⅝	7	2275	805	207	40	1380	66
15½	4⅜	8⅞	9	1760	1377	353	70	2420	1 13
19	5½	10⅞	11	1435	2050	525	105	3620	1 68
22½	6½	12½	13	1215	2930	752	150	5175	2.40
26	7½	14½	15	1050	3880	995	200	6900	3.18
29½	8½	16½	17	928	5040	1290	260	9000	4 13
33	9½	18⅜	19	825	6350	1630	325	11200	5.20

expense as the plant grows, and freedom from any danger of destruction by lightning or settling of foundations. There is also the possibility of reducing the temperature of the flue gases by use of economizers much below that possible when natural draft is used.

Figures given by Walter B. Snow in an article on mechanical draft for stationary boilers are interesting in this connection. A chimney 100 ft. high, discharging gases at 500 deg. F. with the external air at 60 deg., will give a draft at the base of the stack of about 0.65 in. If the gas temperature be lowered to 300 deg., the chimney must be 150 ft. high, and if lowered to 200 deg. the height must be 240 ft. Thus for any reasonable height of chimney a large heat expenditure is required to produce draft by the chimney method, the fan system needing only about 1/75 as much. It is, therefore, possible by reducing the temperature of the flue gases to save enough heat to run the machinery for the draft system; in fact, tests made by Wm. R. Roney show an average saving of about 15 per cent of the heat lost in the chimney by using the fan system.

Mr. Snow gives as the cost of different mechanical draft systems: For the single fan forced draft with direct connected engine and short stack, 20 per cent of the cost of brick chimney. For the single fan induced draft, 30 per cent, and for the 2-fan induced draft, 40 per cent. The last mentioned system is only necessary where absolute insurance against shutdown must be provided.

TABLE II.—FAN CAPACITY FOR INDUCED DRAFT

DIAM. WHEEL INCHES	WIDTH AT PERIPHERY	DIAM. OF INLET	SIZE OF OUTLET, INCHES SQ.	SPEED R.P.M. FOR 1-IN. DRAFT	CAPACITY OF FAN IN CU. FT. PER MIN. TEMP. GASES 550 DEG. F.	H.P. BOILER CAPACITY FROM FAN CAPACITY	LB. COAL PER HR. AT 5 LB. PER H.P. HR.	EVAPORATION PER HR. AT 34.5 LB. WATER PER H.P.	BRAKE H.P. TO DRIVE FAN AT SPEED	CUBIC FT. AIR PER MIN. FOR COMBUSTION TEMP. 62 DEG. F.
30	13	20	18	575	4,150	100	500	3,450	1.9	1,950
36	15⅜	23	21½	480	5,570	180	650	4,480	2.5	2,535
42	17¼	26	24½	410	8,450	195	975	6,725	3.8	3,800
48	18¼	30	27	355	9,450	218	1090	7,515	4.5	4,025
54	21	34	30½	329	11,700	270	1350	9,310	5.6	5,265
60	23¾	38	34½	285	14,450	335	1675	11,560	6.8	6,530
66	26	42	37½	260	17,800	410	2045	14,150	8.5	7,960
72	29⅜	46	41½	240	22,550	520	2600	17,930	10.7	10,130
84	34⅜	53	48	205	30,500	705	3530	24,350	13.5	13,770
96	38¼	60	54	180	37,550	865	4325	29,850	17.5	16,860
108	42⅞	68	60	160	46,500	1070	5350	36,850	22.5	20,870
120	47	76	66	140	56,500	1305	6520	45,000	26.5	25,450
132	51½	84	72	130	70,500	1630	8150	56,150	33.5	31,800
144	56	92	78	120	84,550	1950	9750	67,200	39.5	38,000

Forced vs. Induced System

Forced draft has the advantage of being easily applicable to old installations for increasing the capacity of the boilers and is less in cost because large fans can be used, run at slow speed and handle only cool air. The life will, therefore, be longer than for the induced draft fan, which must handle gases up to 500 deg. F.

Cost of installation and cost of power are in favor of the forced system. The gases handled by the induced draft fan are of much greater volume, and, therefore, greater power is required to move them and also they must pass through the fan at a higher velocity, which again increases the power. With the induced system, however, an economizer may be installed in the uptake to good advantage, and the draft necessary to take the gases through this economizer supplied by the fan, which obviously cannot be done in the forced draft system.

The weight of gases handled by the induced system will be from 4 to 6 per cent increase; the volume to be handled would be nearly twice as great. In designing a forced draft system 150 cu. ft. of air should be allowed a minute for each square foot of grate surface. This is an allowance of 240 cu. ft. for each pound of coal burned at an ashpit pressure of 1 ounce. For induced draft the common allowance is 1 ounce pressure and 300 cu. ft. of gas per square foot of grate. To draw the air through the grate and tubes needs a draft of 0.5 in., and there will be 25 per cent loss at the outlet from the fan and 10 per cent loss in the pipes, so that a draft of 0.7 in. of water should be provided at the inlet to the fan. The power used by the fan system will be from 1 to 5 per cent of the entire power generated by the boilers, depending on the size and efficiency of the plant. In arranging a draft system, it should be remembered that the power required to drive it is proportional to the cube of the speed of the fan, so that it pays to run the fan at low speed.

When forced draft is used, the air is usually supplied from a duct carried across the front of the boilers and having openings leading to the ashpits. Each branch is provided with a special damper to regulate the amount of air flowing to that particular boiler. When installing forced draft in connection with a new plant it is frequently found better to lead the air to the ashpit through the bridge wall or side walls, thus heating it before discharging to the fire. The place of the fan in the plant can be chosen to suit the special requirements of each installation.

Fan Drive

Fans may be driven by direct-connected engine or electric motor, or by belting or rope drive from a countershaft. The engine has, however, certain advantages because the electric motor is not well fitted for service in locations where there is high temperature and a great amount of dirt. The direct-connected engine works along regardless of the temperature so long as proper lubrication is provided; the speed is easily varied to any degree and the exhaust steam can readily be used for heating feed water. The direct-connected engine has also the advantage that a low fire can be started under the boiler by the natural draft in a short stack and as soon as a few pounds pressure is available the fan engine can be started and the pressure rapidly increased.

In the induced draft system the fan may be placed on top of the boiler or on a steel framework above the boiler, if so desired, thus saving the space which would be required for the erection of a chimney. If space is a prime consideration the boiler may also be installed of somewhat less capacity than for ordinary draft and the draft pressure increased so as to burn as high as 40 or 50 lb. of coal per square foot of grate per hour.

With mechanical draft it is often possible to burn a cheaper grade fuel than could be used with natural draft because the draft pressure can be increased to the amount necessary to force air through a closely packed bed of fine fuel, even when the percentage of ash is high and considerable clinker is formed.

The tables shown herewith give valuable data as to the size of blower needed for forced draft and the size of fan needed for induced draft.

In choosing a fan it is better to allow too much than too little capacity. Cutting down the speed lessens the power used and leaves a margin for added load; increasing the speed is always undesirable.

SIROCCO MECHANICAL DRAFT APPARATUS

American Blower Co., Detroit, Mich.

About 1897 S. C. Davidson, of Belfast, Ireland, invented a radically new type of centrifugal fan which he gave the trade name of Sirocco. The inventor discovered that by providing a relatively large intake chamber, practically unobstructed by the projection into it of blades or other parts, and by employing blades which extend as short a distance from the periphery of the fan inward as is consistent with strength of construction, that vibrations and eddies were minimized and the velocity and volume of fluid discharged for a given speed of revolution were greatly increased.

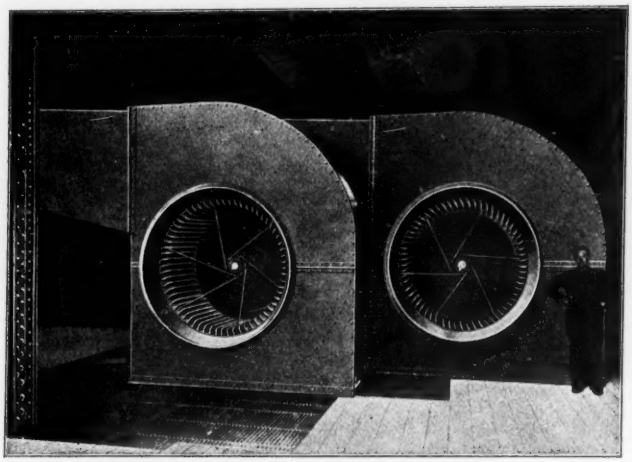


FIG. 1.—INSTALLATION OF 70 SIROCCO FANS

The discovery led to the provision of a means for constructing and operating a centrally rotating narrow bladed fan of cylindrical form with a large variety of forms, all cylindrical, with large intake chambers and narrow blades, axially rotated and differing from each other only in the shape and size of the fan blades, their relations to each other in peripheral or circumferential adjustment, and the relation of casing to fan.

The constructional details of the Sirocco fan were decidedly out of the ordinary in previous American fan practice, the distinguishing features residing in the blast wheel or runner. With the hub is combined a cast-iron cone extending slightly toward the fan inlet. To this cone are attached eye-bolts and drop forged tie-rods forming braces, assuring of maximum strength and rigidity.

For induced draft work, it is standard practice to employ bearings of self-aligning, ring-oiling and water jacketed type; this being the best practice known for this class of work. The inlet of this fan is about twice the area of the outlet, and it is necessary to observe this in order that the fan may deliver the expected volume of air.

One of the principal advantages of a Sirocco fan is the possibility of making the inlet as large as the full diameter of the wheel, whereby the velocity of the air into the fan can be very low. Whatever resistance there may be at the inlet of any fan, detracts to that full extent from the effect that otherwise would be obtained at the outlet. The greater velocity the air has to get into the fan, the lower would be the velocity from the outlet. It is in this direction that large savings in horsepower are effected.

Having a high mechanical efficiency, the Sirocco fan is economical in power and its range of speed is suitable for direct connection to reciprocating engines, steam turbines, or electric motors. The size of the Sirocco fan can be adjusted to almost any requirements of volume, pressure, or confined space.

ARGAND STEAM BLOWER

McClave-Brooks Co., Scranton, Pa.

With forced draft underneath the grate the stack draft is reduced to a point which retards the gases long enough for them to ignite and causes them to roll in the combustion chamber, thereby aiding the combustion, and thus the boiler can be heated more effectually than by the radiant heat alone which is emitted from the incandescent carbon and radiates against a small portion of the heating surface only.

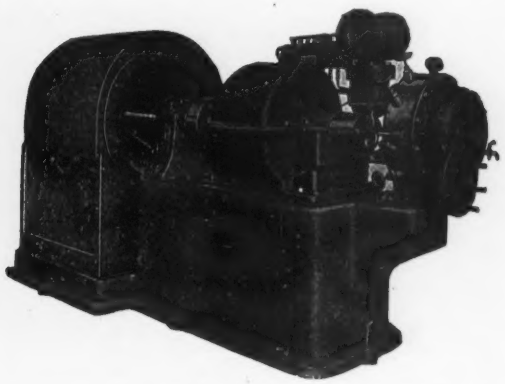


FIG. 2.—SIROCCO FAN DRIVEN BY STEAM TURBINE

To produce this beneficial result the Argand steam blower has been designed which is placed in the boiler setting beneath the grates and consists of a series of steam jets which are formed by small holes in the side of a circular ring, to which is connected the steam pipe from the boiler. This series of steam jets is placed inside a funnel shaped tube through which air is drawn and thoroughly mixed with the jets of steam, and this mixture of steam is forced into the ash pit where it is distributed underneath the grates and passes up through the burning coal.

ARGAND STEAM BLOWER

The steam has a mechanical effect in that it keeps the clinkers soft and porous so that the blast will pass up through the entire bed of fuel uniformly. This blast of steam also moistens the fine ashes in the lower strata of the fire and keeps them from being blown up into the burning fuel to choke it by filling the crevices between the particles of the fuel. In this system each boiler is furnished with its own blower and thus prevents the possibility of a complete shut down in case one blower in a battery of boilers is out of commission.

THE GREEN SYSTEM OF AUTOMATIC DRAFT CONTROL

Green Fuel Economizer Co., Matteawan, N. Y.

Herewith is illustrated an automatic draft control system which unites the desirable qualities of forced draft with those of induced or chimney draft. It so

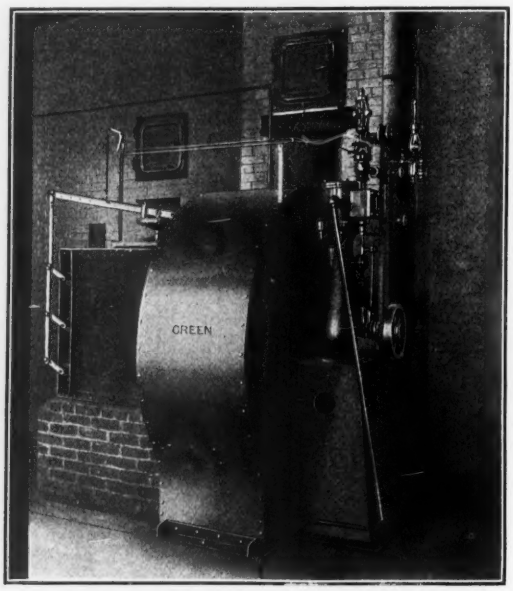


FIG. 1.—GREEN ENGINE AND FAN FURNISHING DRAFT TO BATTERY OF BOILERS

regulates the flue damper and the fan engine in combination that a neutral pressure is maintained in the furnace, just enough draft being supplied by the fan to propel the gases through the fire, while the chimney supplies just enough draft to draw the gases out through the boiler and up the stack. Moreover as the apparatus is controlled by the steam pressure, it serves to maintain a uniform steam pressure at all times.

As the result of maintaining a neutral draft in the furnace itself, there is no leakage of air or gases inward or outward, no waste of heat occurs, either by escape of gases or infiltration of air, and the boiler setting is protected from overheating or chilling.

The system of operation will be more clearly understood from Fig. 3. The controller, located near the forced draft fan at A admits water pressure to a line of 0.5 in. pipe running to an actuator at B, which operates a damper in the chimney flue. A second controller at C, admits water pressure to an actuator or damper motor at D, which operates louvre dampers in the discharge of the fan at E. This same controller C, admits water pressure to the diaphragm or piston valve F, which controls the admission of steam to the engine and slows down the engine driving the fan at the same time that the fan outlet is throttled.

By controlling the speed of the fan a considerable economy in steam for driving is effected. The chimney flue damper at B, is arranged to close a trifle later than the fan dampers to avoid the possibility of any

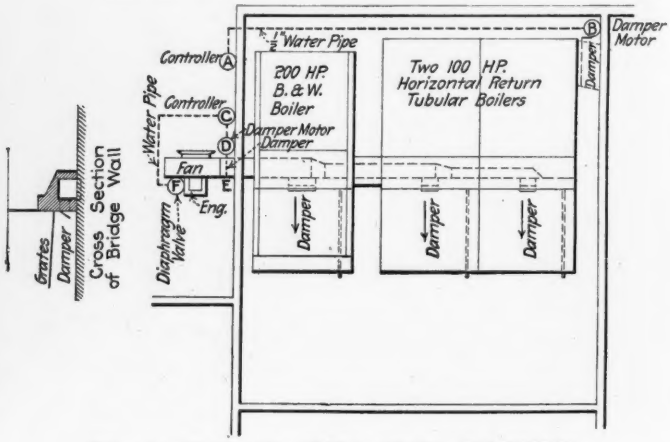


FIG. 3.—PLAN OF GREEN DRAFT EQUIPMENT FOR 3 BOILERS

gas being forced out through the fire doors by the operation of the blast fan.

The arrangement by which the air is carried from the blast fan through a brick conduit under the bridge walls to the separate furnaces is apparent in Fig. 3. Each outlet is supplied with an independent hand-op-

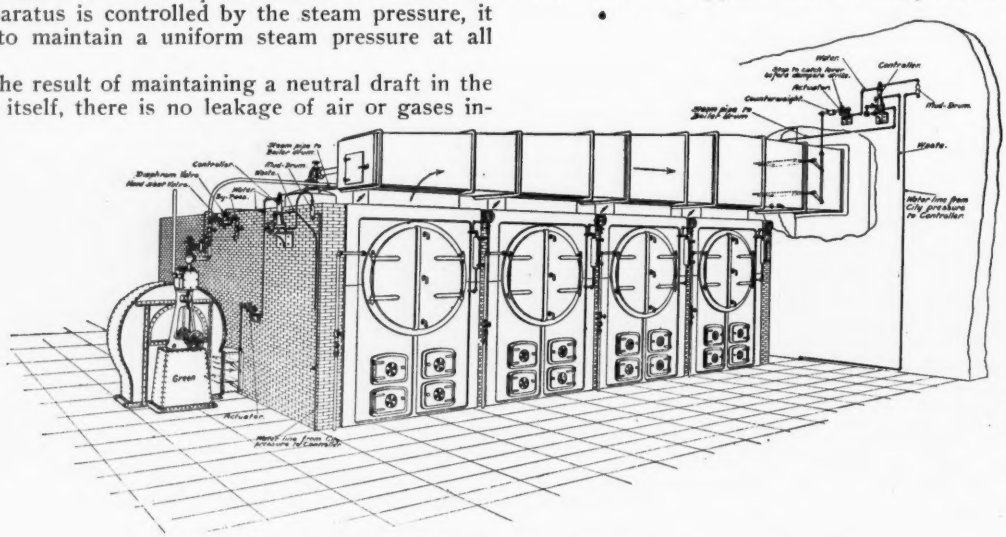


FIG. 2.—ARRANGEMENT OF GREEN AUTOMATIC DRAFT CONTROL OUTFIT

erated damper, the purpose of which is to make up for any differences in resistance of flues and air passages as between the different boilers. For instance, the draft induced by the chimney in the uptake of the nearest boiler might be 0.3 in. and in the one farthest

away but 0.1 in. In the same way the pressure from the fan might vary from boiler to boiler, but all these differences can be adjusted by the independent dampers in the ashpits, which also provides for working any one boiler heavier or lighter than the others, as desired.

THE TURBO BLOWER

The Turbo Blower Co., New York, N. Y.

This apparatus for producing a mechanical draft is so made as to be self-contained, occupying no space

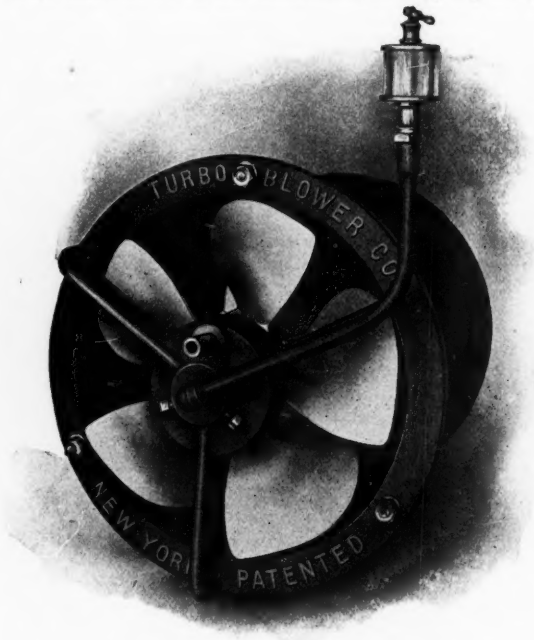


FIG. 1.—THE TURBO-BLOWER

outside of the boiler setting, the entire length of the casing being set into the masonry. It can easily be installed in any type of boiler and may be placed in the front, side, or rear, according to conditions. All parts are of such strength that the apparatus is in no danger from the rough usage of the boiler room; wearing parts being fully protected from dust and ash require no attention other than occasionally filling the oil cup.

The turbo-blower is made to be controlled by hand, or if connected with a damper or other regulator its operation becomes entirely automatic.

The steam supply enters through a pipe into the steam chamber, from which expansion nozzles lead it to the buckets of the turbo blower. There may be 1, 2, or more nozzles, depending upon the requirements. After striking the buckets and propelling the fan, the steam is taken up by exhaust vanes, placed behind the turbine ring, and is ejected from them through an orifice and mixed with the air supplied by the blower. The turbo-blower therefore presents all the functions and the advantages of a steam jet, blower, and an engine. These blowers are made in various sizes to serve boilers from 60 hp. up. It is claimed they are of particular value when it is desired to burn low grade fuel, maintain a uniform steam pressure, or to develop power in excess of boiler rating.

TYPHOON TURBINE BLOWER

L. J. Wing Mfg. Co., New York, N. Y.

One modern method of producing draft is the Typhoon turbine blower. In itself it is a combination of an up-to-date turbine engine designed to obtain the maximum work from the steam with a rotary fan of the helicoid type. Figure 1 shows plainly how this combination is effected to produce an efficient working unit.

The hollow cored steam chest, with its 0.5-in. steam inlet, holds the nozzle. The steam issuing from the latter impinges directly on the buckets cast by a special process into a bronze ring, to which is fastened the fan proper.

The bearing consists simply of a bronze bushing which rotates on the fixed hollow steel shaft, steel surfaces forming the end thrust. The bearing is made dust proof by a cap screwed over the hub of the fan, and the whole rotating element is suitably enclosed in a cast-iron casing for complete protection.

Figure 2 shows well the ability of the blower to be placed directly in the boiler wall, thereby saving costly floor space, giving separate boiler control, and doing away with repairs, supplies and constant attention.

Operated automatically by the damper regulator, the Typhoon turbine blower gives a unit which is capable of great flexibility, whose steam consumption is exceptionally low and whose broad range of air delivery and pressure enables all low grade fuels to

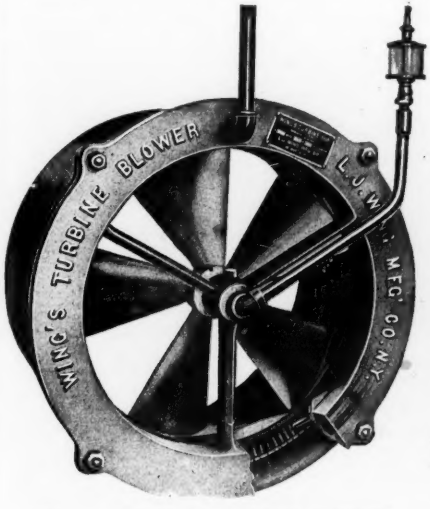


FIG. 1.—TYPHOON TURBINE BLOWER

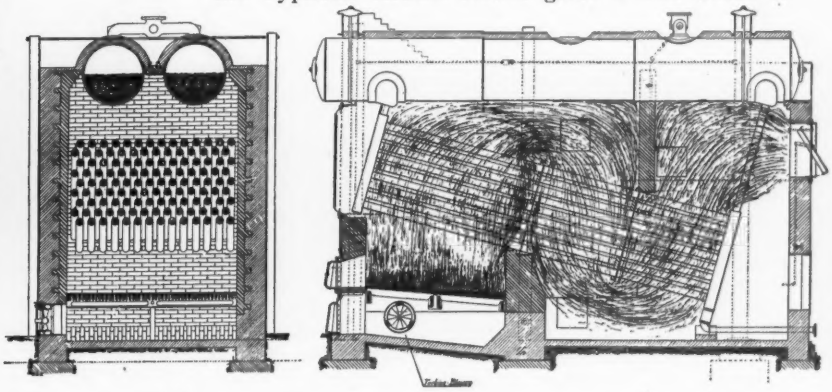


FIG. 2.—TYPHOON BLOWER APPLIED TO A BOILER.

be burned properly and efficiently, giving at the same time a marked increase in the capacity of the boiler.

The blower is made in 4 sizes, namely 12, 16, 20, 24 in., suitable alone or in combination for any size boiler.

STURTEVANT MECHANICAL DRAFT SYSTEM

B. F. Sturtevant Co., Hyde Park, Mass.

The design, construction and installation of mechanical draft systems both under-grate and induced as built by this company are so individually considered to suit the exact requirements of the plant in which they are to operate that it is difficult to give any fair description of their mechanical draft apparatus which could be called standard.

This company considers that the engineering problems of mechanical draft are of the greatest importance, and is most particular about making a study of the local and individual operating conditions of each plant in which it is to install mechanical draft, and then build apparatus to operate most satisfactorily under the working conditions of that plant and to give the largest percentage of fuel economy.

A choice of 3 regulations to maintain constant steam pressure is offered; mercury regulator for particularly fine work, balanced lever valve with damper regulation, and the spring valve regulator which is more often used with simple induced draft.

The Sturtevant Co. builds its own engines, turbines, and motors and furnishes any of these 3 drives with its mechanical draft fans, and the systems it installs have water cooled bearings where necessary and such other special features as tend to make a system perfectly designed and installed.

FURNACE BRICK WORK

IT is not proposed to treat here the subject of boiler settings in general. While that is an important subject, it does not concern directly the action of the furnace except that the brick work should be so thoroughly laid that no cracks or air holes are permitted. The brickwork in the furnace proper must be constructed of firebrick, arranged so that the part of the furnace lining next the grates can be renewed without disturbing the rest of the setting, as this lining will last but a short time as compared with the rest of the boiler setting.

The method of laying up firebrick is so carefully discussed in the article following this that it is not necessary to take up the matter further.

As to the quantity of brick needed, this will vary, of course, with the type of setting adopted, as well as with the size of boiler. For a horizontal tubular boiler 36 in. by 16 ft., with the ordinary setting, 700 firebrick are needed for the half arch construction, and this will take 1.25 barrels of fire clay. For a 60 in. by 16 ft., 900 brick will be needed and 2 barrels of fire clay. For a 72 in. by 18 ft., 1,500 brick will be needed and 3 barrels of fire clay. If the larger furnaces recommended for smokeless combustion be used, the firebrick must be increased in direct proportion. Any figures for the amount of furnace brick needed for water-tube boiler settings cannot be given because the settings vary so widely with the type of boiler. The manufacturers usually furnish this information.

FIRE BRICK SHAPES FOR BOILER SETTINGS

By H. A. Phillips

AS ALL refractory materials are popularly called fire brick I will state that this treatise is devoted to shapes made of fire clay, i. e., silicate of alumina, and chemically designated as acid, where the silica predominates; basic where alumina does, and neutral where the proportions are approximately equal.

The majority of fire bricks are in the first mentioned class (acid) and it is quite generally believed that silica is the most important ingredient, but conditions under which they are to be used determine this entirely, and in cases where the fire brick will come in contact with any alkalies the silica will be attacked and fail utterly. To go into this feature thoroughly in this article is out of the question and is mentioned merely to show that only those makers who combine technical with practical knowledge can obtain the best or even mediocre results.

Physical Requirements

Physical essentials are much more commonly known, but in these also knowledge is conspicuous by its absence. It is not uncommon for the claim to be made that a particular make of fire brick will stand

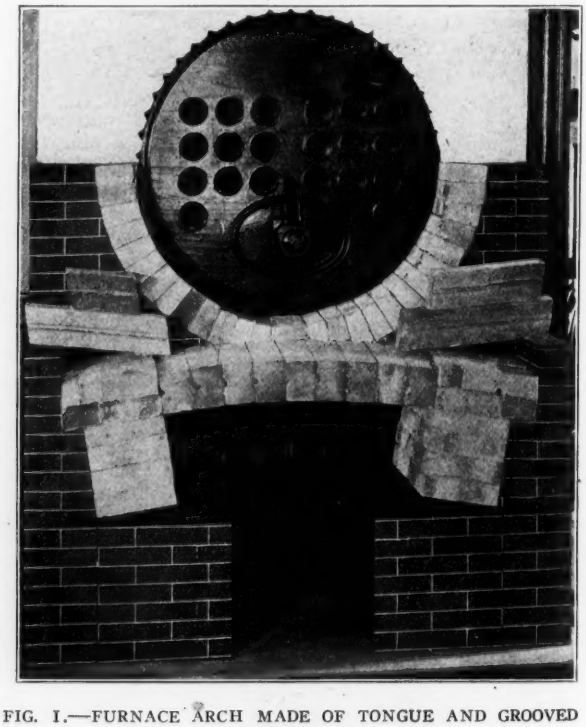


FIG. I.—FURNACE ARCH MADE OF TONGUE AND GROOVED BRICK

the greatest amounts of both abrasion and heat, although the characteristics that create one of these virtues are diametrically opposite to those of the other. In other words, a loose, soft fire brick will stand more heat than a close, hard one. Crushing strain, expansion, contraction and many other features must also be reckoned with.

True economy in fire brick settings for boilers or

any other furnaces can be obtained only by taking the conditions under which they are to be used into consideration. The most progressive makers of fire brick agree that there are no clays in any one section that are suitable for all purposes so recommend their product for use under certain conditions, or for certain purposes, or procure clays from different sections so mixtures can be made to meet various requirements.

While on this subject, mention of various processes of manufacture is apropos. The method for each plant must be determined by the character of the materials to be used. Trying to make fire brick by a wrong process has made a real success impossible for many manufacturers and a total failure for some.

Materials and Processes

Materials that can be worked by the soft mud process and are properly moulded by hand have no superior. By the soft mud process is meant the mixing of plastic clay with ground fire brick, particles of silica, shale or other material that will not shrink under high temperatures. Of these materials ground fire brick or pottery ware is superior, as it has been calcined or heated to a temperature that precludes further shrinkage. The necessity for using some non-shrinkable is that clay by itself will crack when subjected to a high temperature.

When particles of silica are used, the fire brick is very likely to be spongy, as the silica expands and contracts at different temperatures more in proportion than the burned clay, so when brick cools, a space is left betwen the particle of silica and the pocket it has formed in the clay.

A cheaper and correspondingly poorer process for working plastic clay is by mixing it in an auger machine and as the mud is forced through the outlet or die it is in the shape of a number of bricks laid together; then by use of a series of wire cutters this, as it might be termed, bar of clay, is cut into the required lengths.

Shapes moulded by auger machine have a spiral grain or lamination, to eliminate which no method has yet been discovered. This characteristic frequently necessitates cutting several bricks before a bat of the desired shape is obtained; it also creates a tendency to peel off, especially when laminations are close to the surface.

In the dry pressed process, the non-plastic clay or shale is pulverized and in this shape used to form the body. With it are mixed larger particles of the shale to serve as non-shrinkables.

Users of fire brick shapes that have to be made should realize that one of the surest ways to obtain defective pieces is to wait until the last minute before ordering, then expect the fire brick manufacturer to make, dry and burn the shapes as quickly as an iron moulder casts a grate bar or a boiler-maker rivets a patch on.

Outline of Process

The following brief description of clay working may have some effect. Under the best conditions, viz.: where the maker has the necessary moulds and a mixture suitable for the particular purpose ready when the order is received, he assigns the moulding by methods similar to those in other factories, and the shapes are made. Right here the similarity to work with which most fire brick users are familiar, ceases.

Time for proper drying is absolutely essential as by forcing the moisture, water, out too rapidly cracks or crevices inevitably result and it is impossible to know to what extent this injures a piece, the defects in which will not show until it has been set and put in service.

After the shape has been dried properly it must be held until there are enough others to fill a kiln, as proper burning is impossible unless a certain space is filled. Burning is simply another, or rather a more thorough, drying, as fire clay is changed to fire brick by driving the moisture out of it and, if heated too suddenly, steam is made inside the shape and the force it exerts to get out is liable to shatter the shape. When this happens, it means to start all over again, resulting in loss to maker and further delay for customer. A month is none too long for the proper making and burning of special shapes, although under exceptional circumstances small shapes can be made in less time.

Special Requirements

To cite specific cases in boiler practice we will consider arches over charging door opening. Here we have, first, high temperature as the destroying agent, while abrasion is negligible; second, unequal expansion, as the heat is greater at the center on the rear and gradually less in all directions until it is practically cold at the ends on the front; third, sudden cooling, each time the door is opened to put on fuel. These conditions are universal, except the last, which may be eliminated by use of a mechanical stoker.

These factors indicate a loose, porous (consequently soft) fire brick to stand heat and also sudden changes in temperature, made in sections so the joints will permit expansion or contraction at any point or points without straining the body of the fire brick, which is the cause of cracking large tile when used for this purpose.

This tendency to crack and the necessity of having tile made especially for each boiler front, are the objectionable features of using such tile and have caused many who tried them to return to the old style arch composed of regular arch or wedge bricks, notwithstanding the excessive cost of labor by high-priced mechanics and loss of use of boiler during rebuilding. Where attempts have been made to save by using inferior workmen to set these arches, the result has proved expensive, because if such arches are not properly set (and not infrequently when they are) the clay dries and falls out, causing the entire structure to collapse.

To overcome these several objections, a manufacturer in Baltimore, Md., has designed tongued and grooved blocks 4.5 in. thick, of different tapers, so when laid side by side, arches of numerous radii can be constructed without requiring any clay, as the taper makes the desired shape and the tongues and grooves break the joints. Arches of this construction can be built nearly flat, as the joints will take care of any ordinary expansion, and by giving the arch a rise only 1 in. in a span of 36 in., any extraordinary expansion will merely raise the center without cracking the section or weakening the structure.

The comparative dimensions of these sections have been figured out to such a nicety that the maker can supply from stock those required for either level or splayed arches, for any ordinary depth in 1 ring.

A decidedly economical feature of this construction is that it is entirely independent of piers or jambs, being supported by fire walls. This permits repairing or renewing jambs without affecting the arch, that ordinarily lasts much longer than jambs which are constantly being knocked by fuel and firing tools. Furthermore, those sections of side walls that sup-

port the arch are protected by the jambs, so remain good even longer than the arch.

Arches for Mechanical Stokers

Mechanical stokers which are coming in use more and more, frequently require arches with almost no rise in proportion to the span, in some cases rings with 10 to 11 ft. span and rise of 7 to 10 in. are used. The physical conditions to be considered are the same as those for the arches just described, with the addition of ability to stand greater crushing strain.

These arches are set with one or more rings at the front nearly level and each succeeding ring set a trifle lower, dropping proportionately more at the ends than at the center. The result is some rings with, say, 7-in. rise in a span of 10 ft. and graduating to, say, 17-in. rise in the same span.

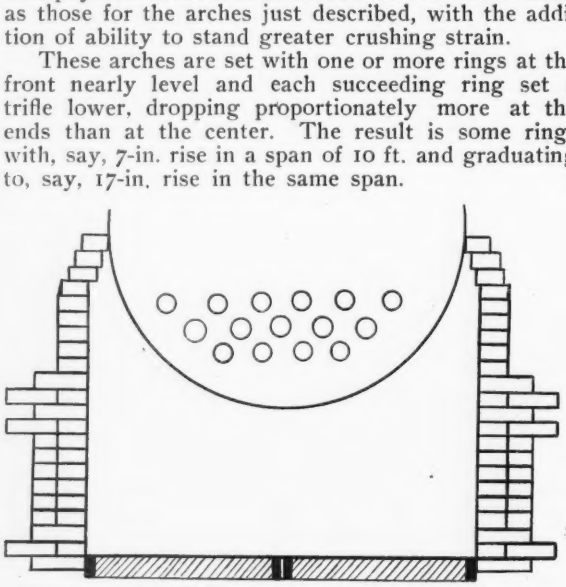


FIG. 2.—CORRECT METHOD FOR BUILDING A FIRE WALL

These conditions make special shapes impractical, but button bricks have proven the solution. These bricks are the size of standard 9-in. straight, arch or wedge bricks, with 8 buttons, or hemispherical knobs, on 1 flat side and 8 concavities on the opposite side.

Buttons and concavities register, so bricks can be laid side by side without all edges flush, or joints be broken in almost as many ways as they can, where ordinary flat-faced brick are used.

Button bricks have given great satisfaction where poor foundations have caused walls to crack, as the bond is so positive even without clay that they cannot slip, consequently for a crack to extend through more than 1 course, the strain must be great enough to crack the body of a brick in the next course.

These cracks almost invariably start in the clay or mortar between the ends of 2 bricks, then along the flat side to the next perpendicular joint; so by preventing the horizontal slipping the perpendicular joints are guarded.

Building Arches

No clay or mortar is necessary to set either tongue and groove lintel or button brick arches, either of which is set over a center, with skews at each end and set from 1 end to the other, not keyed.

By leveling the skews at the ends to correspond to the radius of the arch, they form a wedgelike support permitting the arch to raise or lower in its entirety when affected by heat.

After skewing, remove the center and then grout with a thin solution of clay and water. Where button bricks are used for walls the best results are obtained by dipping each brick in the clay the same as in ordinary fire brick work. Great care should always be exercised to make thin joints in fire brick work, as the green clay first dries then falls out before it becomes brick; also the total shrinkage in many courses of bricks sometimes amounts to enough to considerably weaken the structure.

In deciding the requisites for fire wall, it is necessary to consider the temperature ordinarily used; to what extent does the coal generally used slag and attach itself to and have to be knocked from the fire brick; does the coal contain an extraordinary amount of any chemical element that attacks either silica or alumina and do walls have to support any extraordinary weight?

Fire Wall Construction

In setting bricks for the fire wall, always set courses of headers so the upper part will not fall while the lower part is being repaired. A good method of assuring safety here is to lay a course of headers at the grate bars, then a course of stretchers backed up by headers, then a course of headers; above this 7 courses of stretchers, backing the 7th with headers, then a course of headers, then a course of stretchers, backed up by headers; another course of headers and stretchers from there up, as shown in Fig. 2.

By this construction the first course immediately above the grate bars is a stretcher, which will not have as much wear as the second course, which being headers, holds it in position, so it is not likely to be pulled out. Even should it be, it is not a hard matter to insert another one in place of it. The greatest wear is at that point occupied by the seven courses of stretchers, and this construction permits them to be replaced with very little danger of having the upper work come down. The headers which back the seventh course tie into the 3rd row and make a firm support that will probably hold, even if the 2nd row should become loose, and by being set in, break the perpendicular straight joint as well as support the row of headers in the next course. The ideal construction for any brick work is that which binds the component parts into 1 compact mass.

Bridge Walls

This brings us to the bridge wall, to which few people pay any attention not realizing that it is the entrance to the space or chamber in which the carbon monoxide, released by burning the coal, combines with the oxygen of the secondary air, on the perfection of which depends the utilization of heat units and efficiency of the boiler.

The main consideration regarding the material of which to make this is ability to withstand heat, as it soon becomes encrusted with slag which protects it from the firing tools.

The shape and size of the bridge walls, in proportion to furnace and boiler, regulates the amount of secondary air admitted to sustain the combustion, and ordinarily there is no other provision for regulating the amount. To overcome this objection the Baltimore Retort & Fire Brick Co. make a special block that they call Airport bridge wall block.

These blocks have ports through them that connect with an inlet through fire walls, so air is preheated by radiation before it enters the combustion chamber. The supply is regulated by a simple device along the side of the charging door.

That the heat resulting from this combustion goes where it will perform the desired work is of no less importance and many methods and appliances have been devised to accomplish this. The greatest objection to many of these methods is that metal is used

in their construction, and the extreme heat either destroys or warps it, so it deteriorates very rapidly, and its cost is not inconsiderable; also that for most of them a bar of iron has to be fastened to the boiler head to support 1 end of the arch and fill space between the edge of the arch and the end of the boiler to provide for the expansion of the latter.

Great care is necessary in estimating the space required, as this iron is a weak spot, consequently must be reduced to a minimum, but must be of sufficient size to permit all possible expansion, otherwise any expansion in excess of that estimated will push the arch back and crack the rear wall. The frequency with which the cracked rear walls appear leads us to believe that correct estimates are the exception.

As is not unusual, these objections have been overcome by a device more simple than any other used, which is shown in Fig. 3, and consists of a fire brick block with a curved groove moulded crosswise near 1 end. This block is set in the rear wall with the groove side up and extending in, so a curved tile can be rested in the groove; the other end of the tile leans against the boiler head just over top row of tubes.

These tile and supports are made 12 in. wide and the tile have rabbitted sides to break joints; laid side by side they form a gas-proof arch conforming to the natural current of the gases passing from under the boiler into the tubes.

The boiler expanding merely pushes the tile nearer perpendicular and several times the possible expansion would not be sufficient to put any pressure on the rear wall. In other words, the arch rocks back and forth, reciprocating every movement of the boiler, hence its name rocker tile.

Without the fire brick shapes, generally called tube tile and flame plates, water tube boilers would be worthless from a practical standpoint, as it is only by setting these shapes to guide or baffle burning gases that the heat is utilized and the tubes protected from destruction.

Each water tube boiler manufacturer uses designs and dimensions according to his peculiar requirements, but this article will treat them in a general way only.

Considerable trouble has been encountered in having the bottom row of tubes burn out, on account of the intense heat to which they are subjected, evaporating the water contents so rapidly, thereby creating pressure against the inlet, so water could not enter in sufficient volume to prevent a comparatively dry tube which, would naturally burn. By-passes for steam sometimes relieve this condition, but the most effective plan is to use tile with a semi-circular groove, with a diameter slightly greater than that of the tube, running the full length on 1 side and the oposite side being shaped to fill ½ of the space between the tubes, so when laid side by side they hang on the tube and hold each other from slipping off.

That part of the tile that hangs below the center of the tube is rounded, to reduce the thickness of the tile through which heat has to pass, to evaporate the water. This also has the effect of forming a corrugated roof along which all the burning gases will not pass too rapidly. This roof, as it might be called, does not extend the full length of the tubes, but only as far as necessary to protect the tubes from the intense heat and guide it to the desired point for it to pass around the other tubes as described.

The passage of these burning gases among the tubes is regulated by other shapes, some laid horizontally and some perpendicularly.

The materials of which the tiles for the bottom row are made must stand extremely high temperature, and, where firing is done by hand, sudden changes of temperature. It must also be borne in mind that very careful firing is necessary to prevent knocking with coal or fire tools, so a hard burned refractory body is necessary.

Auger machine-made tile for this purpose are far from satisfactory, as the shape of the tile and their positions make any laminations especially liable to cause peeling. For the other tube tile and flame plates, high temperature is the only destroying agent to be considered.

Another use for fire brick is in the numerous smokeless, sometimes called smoke consuming, devices. The varieties and shapes used for these are innumerable, some quite simple and many most intri-

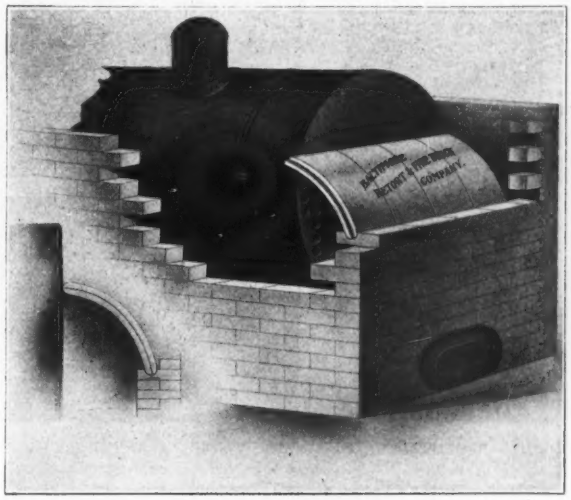


FIG. 3.—ROCKER TILE USED TO OVERCOME BAD EFFECTS OF BOILER EXPANSION

cate. The basis of all these devices is the introduction of air to sustain complete combustion of gases and generally this introduction is in the form of secondary air.

Shapes for these devices can be made only by hand and by experienced workmen, as great care and accuracy on the parts of the draftsman, mould-maker, moulder and burner are required to make the passages, channels, ports and other parts fit exactly when burnt.

Many fire brick makers of national reputation will not accept orders for this class of work, and the buyer would do well to learn the facilities of a manufacturer before placing his orders.

In this respect an exceptional condition exists at the works of the Baltimore Retort & Fire Brick Co., Baltimore, Md., where circumstances have brought together practical men of greatly diversified experience, covering the field from manufacturing false teeth and chemical appliances to large gaseous fired industrial furnaces and boiler settings.

EVENS AND HOWARD FIRE BRICK

Evens & Howard Fire Brick Co., St. Louis, Mo.

Of several brands of fire brick made by this company, the Evens and Howard brand, manufactured from calcined and raw Cheltenham clay with a hard

finish, is especially adapted for linings in boiler furnaces, lime kilns, foundry cupolas and all purposes where a thorough fire-resisting material is necessary.

These bricks are made in all standard shapes, such as the jamb brick, wedge brick for 12-in. diameter circle, circle brick for 36 and 48-in. inside circle, which are

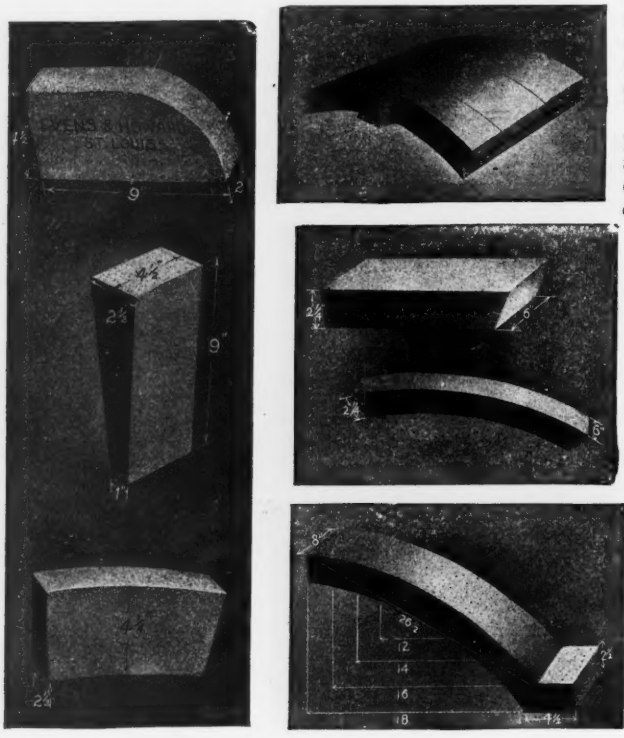


FIG. 1.—PROPORTIONS OF JAMB, WEDGE AND CIRCLE FIRE BRICKS
FIG. 2.—LOCOMOTIVE FIRE BOX TILE
FIG. 3.—SIDE AND CENTER BOILER TILES
FIG. 4.—BACK BOILER TILE

illustrated herewith. Of the special forms we illustrate the locomotive fire box tile, which is one of the many designs now being used. The side and center boiler tiles of the shape illustrated are made in any of the desirable dimensions. A special back boiler tile is also made in the proportions shown in the illustration.

THE "STEEL MIXTURE" BOILER SETTING

McLeod & Henry Co., Troy, N. Y.

The steel mixture boiler setting shown in the illustration is a natural outcome of the ordinary method of lining the boiler furnace.

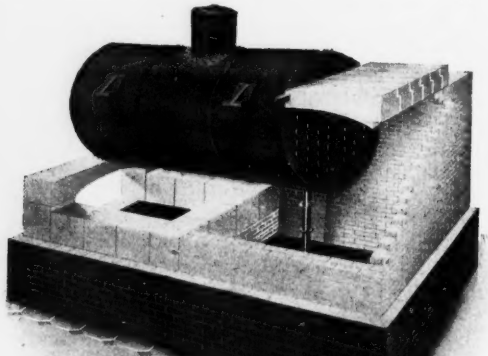
The makers some time ago started to develop a refractory material that could be moulded into large blocks which would stand hard usage when so moulded; steel mixture was the result. It is not only highly heat resistant, but very hard and strong as well.

The idea from the first had been to avoid the weakness due to small brick work with its numerous joints exposed to fire. As finally produced the setting consists of large blocks so jointed together that they are well bonded to one another and present a smooth comparatively jointless surface to the destructive influences of fire and abrasion.

In detail, the setting consists of an arch for the boiler door suitable blocks for lining the fire box, and a cover for the combustion chamber when used with a horizontal tubular boiler.

The boiler door arch is made in a number of different sizes and shapes so as to be able to fit any make or size of boiler. It consists of arch pieces for the required number of openings resting on suitable jambs. The jambs and arch pieces are flared away from the door opening so as not to interfere with firing. The whole arch makes a strong durable form of construction for what has always been a more or less weak point in the boiler setting.

The fire box blocks can be used for a variety of purposes. Ordinarily they are laid up in the form of a smooth wall the height of the fire and entirely enclosing it. They can be adapted to the different styles of bridge walls in use and offer a method of obtaining a hard, smooth and refractory surface in any part of the furnace. They are most useful, however, in the firebox itself where the heat is highest. They are made in sizes 6, 8 and 9 in. thick and 12, 18 and 24 in. high.



STEEL MIXTURE BOILER SETTING

The back arch is known as the Foote's patent back combustion chamber arch after its inventor, John H. Foote. This arch is made up of a number of units and therefore can be made to fit any combustion chamber. It is independently supported by the side and back walls of the setting and a gas tight and elastic cushion of asbestos wool fills the space between the back head of the boiler and the end of the arch blocks. The latter are so designed that they give ample head room for working in the chamber.

HARBISON-WALKER FIRE BRICK

Harbison-Walker Refractories Co., Pittsburg, Pa.

Under present business conditions, the ability of any fire brick manufacturer to make stock shipments is of great importance to the consumer. The facilities of this company enable it to carry large stocks of all standard, and many of the special shapes used in boiler settings, and, with plants in nearly all the fields producing high grade refractory clays, it is possible to make quick deliveries to almost any point. A number of these shapes are illustrated in Fig. 1.

In Fig. 2 is illustrated the method of building up a boiler setting for a typical water tube boiler. In this setting the fire brick is represented in a lighter color than the ordinary brick used in the construction. It will also be noted that the baffles to direct the hot

gases across the water tubes are made of fire brick of special shape, which are manufactured by this concern.

A few directions for ordering and using fire brick as given by this company are as follows: All fire brick should be kept in a dry place, as moisture, especially in cold weather, will greatly injure any brick. In setting the brick, fire clay should be used which is equal in refractoriness to the brick itself, and should be applied very thinly with dipped joints and brick rubbed to make a brick to brick joint. After the boiler setting has been laid, it should be fired slowly to expel moisture.

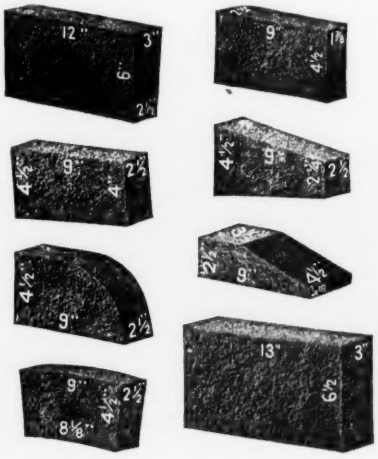


FIG. 1.—STANDARD SHAPES OF HARBISON-WALKER FIRE BRICK

From 250 to 350 lb. of fire clay is enough to lay 1000 brick. Fine ground clay should be used for laying up fire clay brick, and silica cement for silica brick.

The following figures are used in estimating for fire brick work: A 4.5-in. wall requires 7 bricks to a square foot surface; a 9-in. wall, 14 bricks; 13.5-in. wall, 21 bricks. One cubic foot of brick work requires 17 9-in. straight bricks. Fire clay bricks weigh 150 lb. per cubic foot; silica brick work weighs 130 lb. per cubic foot. One thousand brick, closely stacked, occupy 56 cu. ft. One thousand brick, loosely stacked, occupy 72 cu. ft. For estimating on red brick work, figure on 9 cu. ft. of sand and 3 bu. of lime for laying 1000 bricks.

RISLEY DEFLECTING REAR ARCH

The Risley Company, Princeton, Ind.

It is a fact without a doubt that the upper tubes of an ordinary return tubular boiler are much more efficient than the lower ones, by reason of the fact that the heat of the furnace naturally tends to rise to the highest point as it passes to the tubes, and again that the gases must make a short turn and travel in the opposite direction, causing them to take the easiest course which is the greater diameter in making a short turn, therefore the greater portion of the gases passes through the upper rows of tubes, thus depriving the lower tubes of their share of the gases.

To overcome this difficulty, the Risley deflecting rear arch has been designed. This arch is of such shape as to distribute the flow of furnace gases equally through the tubes, thus the lower tubes are just as efficient as the upper ones, and with its use the temperature variation between the upper and lower tubes is kept within 2 per cent.

The standard bars are of special design, being cast with a high main rib, which extends well up into the brick work, thus being protected from the heat. This rib radiates the heat from the inner surface and adds strength to the bar. These bars are provided with holes placed so as to take care of the expansion and contraction, and on the surface exposed to the fire, projections for supporting the masonry are notched at intervals to prevent expansion cracking the bars as is the case with many arches.

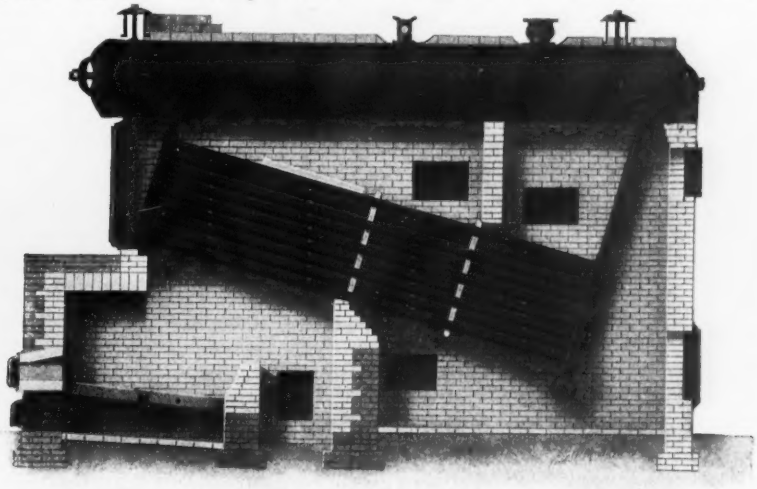
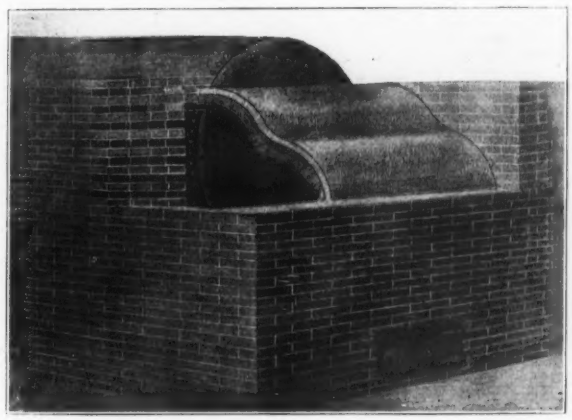


FIG. 2.—HARBISON-WALKER BRICK IN WATER-TUBE BOILER SETTING

QUESTIONS FOR THIRD CLASS LICENSE IN MASSACHUSETTS

A subscriber wishes answers to the following and we would request that answers to these, and the similar questions on page 724 of the December '09 issue, be sent to us in time for publication in the February issue. They should reach this office not later than January 15.



RISLEY DELECTING REAR ARCH ATTACHED TO BOILER

1. If, at night, steam is left up to 70 lb. pressure, with the water glass half full, and the fire is banked so heavily that it smothers and goes out, yet in the morning there is no water in the gage glass, where has the water gone, the blow-off and all other valves being closed tight?

2. What prevents the piston of a pump from striking at the end of the stroke?

3. Why do some pumps have 5 ports while others have but 4?

PRACTICAL ENGINEER

PUBLISHED ON THE FIRST OF EACH MONTH
at 355 Dearborn Street, Chicago, Ill., by the
TECHNICAL PUBLISHING CO.

NEW YORK, 150 Nassau Street.

PHILADELPHIA, The Bourse.

Subscription Price One Dollar a year in advance to any Post Office in the United States and Mexico or United States possessions.

To Canada One Dollar and Fifty Cents; to Other Countries Two Dollars a year. Single copies 10 cents.

Address all letters and make all checks and money orders payable to Technical Publishing Co., 355 Dearborn Street, Chicago, Ill. Notify us at once of any change of address giving the old and the new address so that your paper may always reach you promptly.

Any advertiser is invited to examine our paid subscription lists and Post Office mailing receipts at any time.

Entered as second class matter May 1, 1908, at the Post Office at Chicago, Illinois, under the Act of March 3, 1879.

Circulation of this issue, 20,000.

CONTENTS.

Air Required for Combustion 5
Anthracite Coal 23
Ash Allowable in Coal 38
Ashpit 44

Bagasse as a Fuel 16
Bituminous Coal 25
Brick Work
- Evens & Howard 99
- Harbison-Walker 100
- Steel Mixture 100

Briquets 30
Burning Sawdust 48

Calorimeter
- Automatic Gas 37
- Carpenter 34
- Emerson 34
- Junker Gas 36
- Mahler Bomb 33
- Sarco Bomb Fuel 36
- Thompson 35

Calorimetry 33
Chemistry of Combustion 2
Coal, Estimating Heat Value 32
Coals, Classification of 24
Combustion Chamber 47
Combustion, Chemistry of 2
Combustion, Requirements for Good 62
Combustion, Testing Correctness 6
Combustion of Wood 17

Draft Required 64

Editorials, Fuel Economy, Acknowledgment 103
Efficient Boiler Plant Operation 104

Firebox, The 46
Fire Brick for Boiler Settings, by H. A. Phillips 96
Fire Room Rules 63
Fuels, Composition and Classification 16
Furnace Brick Work 96
Furnace Details 44
Furnaces
- Babcock & Wilcox 65
- Burke Smokeless 66
- Dorrance Smokeless 66
- Harris Smokeless 67
- Hawley Down Draft 51
- McKenzie Dutch Oven 68
- Murphy Automatic 86
- National 69
- Parson 70
- Sullivan Smokeless 66
- Twin Fire 72

Gas Analysis 7
Gas Apparatus
- Elliott 8
- Hays Analysis Instrument 9
- Orsat 8
- Sarco Automatic Combustion Recorder 11
- Uehling Composimeter 10
- Westover CO_2 Recorder 9

Gaseous Fuel 19
Grate Area and Horsepower 64
Grates 44
Grates
- Century Rocking 53
- Glenmore Rocking and Dumping 49
- Gordon Hollow Blast 51
- Hall 56
- Herrick Shaking 106
- Mansfield Ball Bearing 55
- Martin Rocking 52
- McClave Shaking 104
- Neemes Improved 52
- New England 53
- Perfection Shaking 54
- Reagan Improved Chopping 54
- Salamander 55
- Superior Shaking 56
- Willoughby Shaking 56

Hollow Blast Bars 46

Interesting Offer 105

Lignites 25
Liquid Fuel 20

Mechanical Draft 91
Mechanical Draft
- Argand Steam Blower 93
- Green System of Automatic Control 94
- Sirocco Apparatus 93
- Sturtevant System 96
- Turbo Blower 95
- Typhoon Turbine Blower 95

Mechanical Stokers 73

News Notes 107

Oil Burners
- Gem 62
- Hammel 58
- Kirkwood 61
- Koerting 60
- Lunkenheimer 59
- Springfield 58

Oil Burning 57
Oil Burning Furnaces 45
Oil Furnace, Peabody 65
Oil Pumping System, Rockwell 59
Operation of Boiler Plant 104
Operation, Smokeless 40

Peat Fuel 21
Proximate Analysis 32
Purchasing Coal on Specification 38
Pyrometers
- Bristol Electric 12
- Electrical Thermometers 14
- Hoskins 13
- Steel Capillary Tube Thermometer 14
- Uehling Pneumatic 15

Questions for Third Class License in Massachusetts 101

Rates of Combustion 64
Risley Deflecting Arch 101

Sampling Oil 32
Sarco Draft Gage 105
Semianthracite Coal 27
Semibituminous Coal 27
Sizes of Coal 28
Smoke Consumers
- Climax 64
- Coe Draft System 71
- National Forced Draft 69
- North Hot Air Blast 69
- Scharf Automatic 71

Smoke Prevention by Stokers 43
Smoke Recorder, Eddy Automatic 106
Smokeless Operation of Boiler Plants, by Lewis Sanders 40
Steam Jets for Smoke Prevention 42
Stokers
- Babcock & Wilcox 65
- Continental Chain Grate 76
- Crosby System 82
- Crowe Chain Grate 82
- Detroit Automatic 77
- Erie 78
- Erie Traveling Grate 78
- Goetz & Flodin 79
- Green Traveling Link Grate 79
- Illinois Chain Grate 80
- International 81
- Jones Underfeed 88
- LaClede-Christy Chain Grate 83
- Lee 84
- McKenzie 85
- Murphy 86
- Roney, New Model 89
- Swift 87
- Taylor Gravity Underfeed 74
- Universal Chain Grate 75
- Wilkinson 90

Stokers and Smoke Prevention 43

Tan Bark as Fuel 18
Temperature Tests 11
Thermometer, Electrical 14
Thermometer, Steel Capillary Tube 14
Tile Roof Furnace 62
Trade Notes 107

HOW ARE YOU FOR 1910

And may it be a year of joy and prosperity to you all.

FUEL ECONOMY

Fuel conservation is a private as well as a public duty. We as a nation are coming to realize that our fuel supply is not limitless and every pound of coal saved in the operation of a plant is so much gain in delaying the time when the supply will be exhausted. Not only this, but every pound saved is so much money saved to the plant owner. The question is constantly before us, Are we doing our best? and the only means of answering it is by constant vigilance and constant testing, to be sure of actual plant performance. Spasmodic tests at infrequent intervals will not do.

Self protection demands that the man who pays the coal bills should know what kind of fuel he is getting, and this calls for the purchase of coal on a delivered heat basis,—sampling, chemical analysis and checking up of the coal as delivered. This service can usually best be performed by a commercial engineering laboratory, although in large plants where the work is sufficient to warrant providing apparatus it can well be attended to by the chief engineer. The use of calorimeters for determining heat value of fuel is not difficult but requires time and care and somewhat expensive apparatus, so that the commercial laboratory which serves a number of plants can usually perform this service cheaper than it can be done in the plant.

The importance of watching this fuel cost is evident from the fact that fuel constitutes at least 20 per cent of the operating cost of the power plant. Where does this fuel go? W. L. Abbott, of the Commonwealth Edison Co. of Chicago, considering a pound of western coal whose heat value is 10,000 B. t. u., gives the distribution as follows: Ashpit, 300 B. t. u.; stack, 1960; banking fires, 560; radiation, 800; pipe radiation, 370; rejected to condenser, 4810; delivered to busbars, 1200. The condenser loss cannot be eliminated, but the heat may be largely utilized.

The boiler room loss amounts to 36 per cent of the total heat and it needs watching. The ashpit needs to be watched for unconsumed fuel and excessive temperature. The stack needs to be watched for high temperature and unburned gases. The combustion chamber needs watching for air leaks and too low temperature. And all the way through the distribution of draft needs watching for needless resistance to the flow of gases. Mr. Abbott states that 1/5 of the coal bill is paid just to produce draft in the chimney. If there be unnecessary resistance through the fuel bed or boiler passages it increases the amount of this payment. The ultimate index of boiler plant performance is the pounds of water evaporated per pound of fuel. To check this, constant record must be kept or frequent test made of the weights of coal and water used. Keeping tab on what the furnace is doing is just as important as keeping tab on the engine, and in order to get the best possible results from his plant an engineer should become just as familiar with the use of draft gage, pyrometer and gas analysis apparatus as with the indicator; and after he has learned how to use these he should do it even more regularly and systematically than he uses the indicator, for valves once set are likely to stay put for a considerable time, while furnace conditions are subject to continual change, and operating methods must be changed to correspond. Keeping everlastingly at it is the price of success.

ACKNOWLEDGMENT

In the preparation of this issue data and information have been secured from the recognized authorities on power plant practice and from manufacturers and investigators. In many cases direct acknowledgement has been made in the text; where data from several sources have been combined, this has not seemed possible without awkward breaks in the text. It seems better, therefore, to mention here those works from which considerable has been drawn and to thank sincerely the authors and all others who have assisted in bringing together the needed material.

Steam Power Plant Engineering, by G. F. Gebhardt; Steam Boiler Economy, by Wm. Kent; Steam Boiler Practice, by Walter B. Snow; Combustion of Coal, by W. M. Barr; Combustion and Smokeless Furnaces, by Jos. N. Hays; Fuel, Its Combustion and Economy, by D. K. Clark; Gas and Fuel Analysis for Engineers, by Augustus H. Gill; The Calorific Power of Fuels, by Herman Poole; Stirling, by The Stirling Co.; Steam Boilers, by H. deB. Parsons.

INDEX TO VOL. XIII, FOR 1909

This will be ready for delivery Jan. 15 and will be sent without charge to all who send postal card request asking for it.

NONFREEZING LIQUIDS FOR JACKETS

To prevent freezing of water, in cylinders or pipes of the cooling system, when freezing weather is at hand, the water should be drained from the radiator, cylinders and pump of a gas engine, and refilled with one of the following mixtures. First, glycerine and water in the proportion of 25 parts glycerine to 75 parts water by weight, and 2 parts sodium carbonate.

Second, pure calcium chloride dissolved in hot water, 4 lb. of the chloride to a gallon of water.

Third, common salt dissolved in water, 1½ or 2 lb. to the gallon.

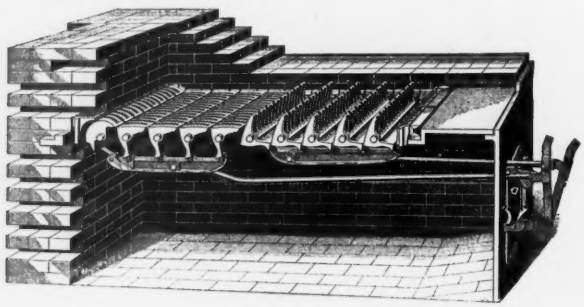
Fourth, a mixture of wood alcohol and water, 20 per cent alcohol to 80 per cent water; if the temperature is to go as low as 15 deg., F., the solution should be 25 per cent alcohol and 75 per cent water; if the temperature is below zero, use 30 per cent alcohol and 70 per cent water. This fourth mixture has the advantage of doing no damage to any of the metal and leaving no sediment.

McCLAVE GRATES

McClave-Brooks Co., Scranton, Pa.

Loss due to opening the fire door of a boiler furnace for the purpose of slicing the fire and removing clinkers has been overcome by this shaking and dumping grate, which is adaptable for use with any of the power plant coals upon the market. During the shaking movement there is no increase in the size of openings of the grate, and this shaking movement is adapted to break up a soft coal fire when it cakes or to remove fine ashes from a hard coal fire when there is little or no clinker formed.

Cleaning of the fire is done uniformily from front to rear by operating each entire row of grate bars as a whole and no uncleaned part is left at the bridge-wall, a feature which is readily appreciated by the fireman.



MCCLAVE GRATE

Each row or section of grate bars is divided into a front and rear series by means of 2 separate connecting bars operated by twin stub levers and connecting rods, with an operating handle adapted to grasp either one or both of the levers in such a manner that the front and the rear series may be operated separately or together. The fire can thus be cleaned of clinkers and ashes dumped without wasting the unconsumed fuel on the surface as that can be shoved over on the stationary part while the clinkers and ashes are being dumped into the ash pit.

Expansion top journal bearing bars are provided, each consisting of a panel bar proper and a continued series of locking caps and key plugs which prevent the grate bars jumping out of their journal bearings while the fire is being cleaned. The grate bars proper are constructed with a supporting rib which is cut down on a bevel below its top edge between 2 fingers; the fingers have a tie cast between each pair at the front to strengthen them and to prevent their warping.

EFFICIENT BOILER PLANT OPERATION

BOILER room economy is mostly furnace economy. After a boiler is once built the handling of it consists largely in keeping it clean inside and out, making sure that ash and soot deposits are kept off the fire surfaces and that scale and sediment deposits are kept off the interior surfaces. The routine required for this is comparatively simple to establish. Regular treatment of feed water where necessary, regular blowing down, regular feeding of the water can be established and maintained with a minimum of superintendence.

The furnace is a different matter. At best, combustion is a complex operation and variations in furnace conditions which will not be noticed may greatly affect the efficiency of the furnace. The final test of boiler plant is comparison of fuel burned and steam made. With reasonably good boilers it may be assumed that all water fed into the boiler is turned into steam, so that weighing of water and coal will give us this ultimate test.

Continuous Test

In order to know what a plant is doing this weighing must be either continuous, by apparatus which is permanently installed in convenient form, or else weighings must be made at frequent intervals under actual operating conditions. The automatic scale is by all means to be preferred, where the size of plant warrants it, to the periodic weighing.

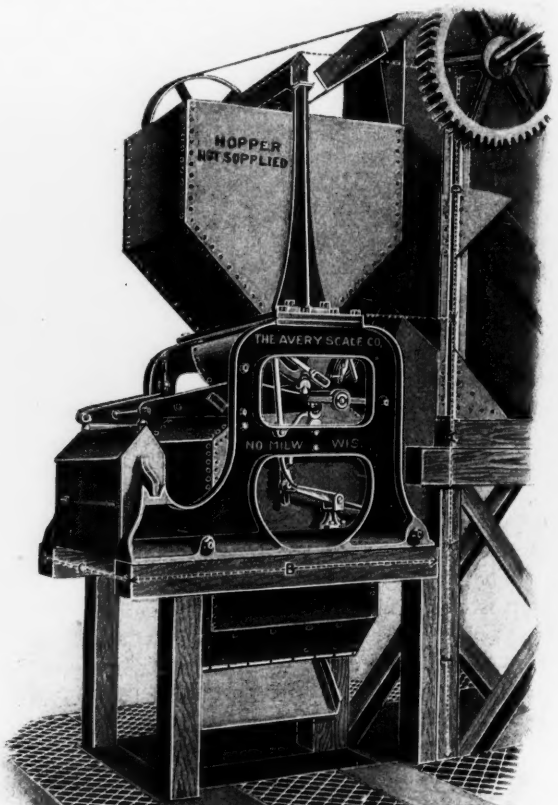


FIG. 1.—THE AVERY AUTOMATIC COAL SCALE

Fig. 1 shows an Avery Automatic Coal Scale which has been specially designed for weighing coal in a boiler house for feeding to mechanical stokers. The scale is built on the even arm beam principle with a weight receptacle on the one end in which standard United States weights are placed, and a weigh hopper on the other end in which the coal is weighed. There is an inlet valve to the scale which is made of a suitable design according to the class of coal being weighed, this valve being opened and closed at each weighing. The weigh hopper is supplied with an outlet valve, so arranged that it is kept closed while the inlet valve is open, and opened when the inlet valve is closed. A registering device is attached to the scale, which automatically counts the number of times the scale dumps, thereby making it an easy matter to ascertain the amount of coal which has passed through the scale. This scale is placed directly under the storage bunker and automatically weighs the coal passing

from this bunker to the mechanical stokers, the coal being delivered down a suitable spout, bifurcated or single according to the style of the stoker which is used. The scale automatically regulates itself to the rate at which the stoker feeds the coal.

If the engineer decides to make a test say for 3 hr., he takes down the reading of the automatic register on the scale at the commencement of his test, then takes the reading again when the test time has expired, and by multiplying the difference of these readings by the amount of dead weights which is in the weight receptacle of the automatic scale, he knows how much coal his boiler has consumed in that time. Also, by the use of an automatic scale, the engineer can tell at the end of the year exactly how much coal each boiler has consumed, which will give him a further check on the efficiency of his plant.

With the automatic coal weighing should go some continuous system of water measurement, either by metering or by weighing. When handling hot water to the boilers the ordinary form of water meter is hardly accurate, as the variation of temperature is likely to affect the meter. Systems of weigh.ng are, however, on the market which will give absolute check on the water used.

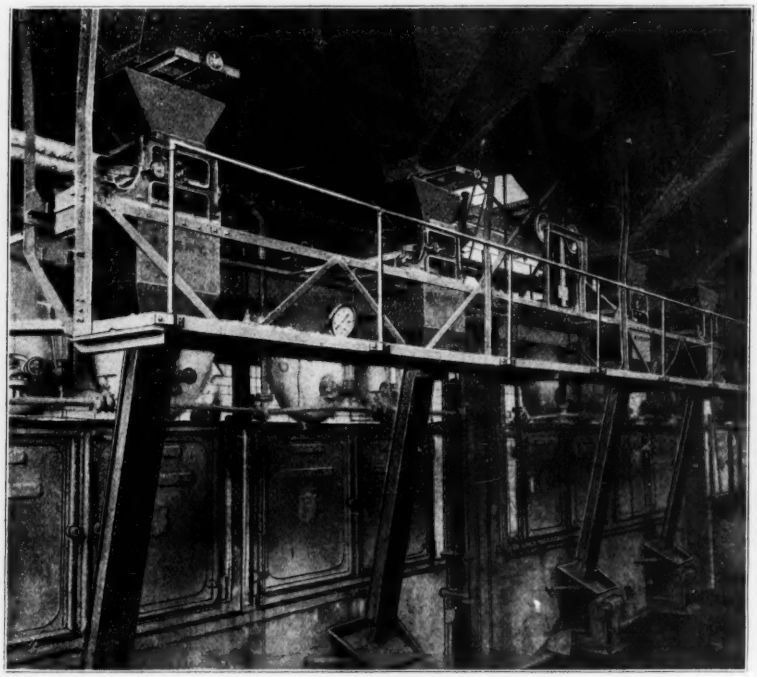


FIG. 2.—INSTALLATION OF AVERY AUTOMATIC SCALES WITH STOKERS

THE SARCO DRAFT GAGE

Sarco Fuel Saving & Engineering Co., New York.

The dial gage, which is of simple and durable construction, and perfectly reliable, is mounted on the front of the boiler in a prominent position. The principle on which the gage works is as follows: A bell floating in glycerine is enclosed in the body of the instrument, which is in communication with the outside atmosphere; a tube enters at the bottom of the instrument and is carried under the bell. The lower open end of this tube is connected with the boiler flue by means of a gas pipe. The draft from the chimney creates a partial vacuum under the bell, which is then forced down by the atmosphere pressure on it. This motion, and thus any deviation in the draft, is transmitted accurately to the dial by means of a rod, to which is attached a toothed segment, and a pinion.

To ensure the advantages of perfect draft, it will, however, be necessary to check the stokers, especially during the night, and at all times when personal supervision is not possible. This is done in a most complete and reliable manner by the recording instrument which automatically and continuously registers on a chart the exact draft with which the stokers are working, and affords a reliable means of controlling the periods of stoking and cleaning.

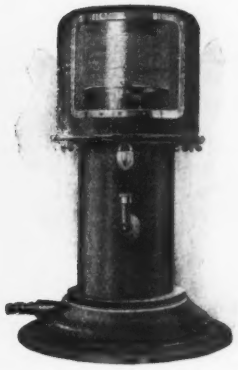


FIG. 3.—THE SARCO DRAFT GAGE

The principle of action is the same as in the dial gage. The drum, which carries a chart for 24 hr., is fitted with a 7-day clock movement.

AN INTERESTING OFFER

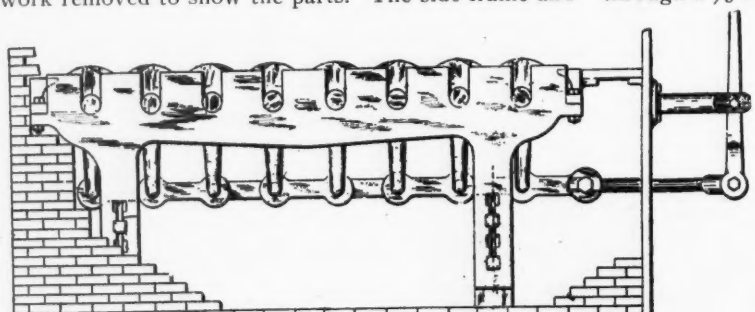
The Magnolia Metal Co., of New York City, are making a special offer to engineers and mechanics to furnish a 650-page Practical Engineer Pocket Book for the nominal sum of 40 cents, postage prepaid. It is hardly necessary to say that this price will nowhere near cover the expense of getting out the book. Those engineers who have been fortunate enough to secure previous copies of the book say that it is invaluable for ready reference and the information in it is always accurate.

It treats on over 2,000 subjects of mechanical engineering interest which of itself shows that it is complete, and inspection shows that it is up to date. If you wish a copy of this book it will be necessary to write the company promptly at the New York address, as the supply which will be available is limited and those who make application first for the books, will make sure of getting them. The books are now nearly ready to mail and will be sent out as fast as they can be completed.

THE HERRICK SHAKING GRATE

George S. Herrick, Syracuse, N. Y.

In the illustration herewith is shown an installation of a Herrick shaking grate with some of the masonry work removed to show the parts. The side frame and



HERRICK SHAKING GRATE

legs are in 2 pieces, and an end grate is placed at each end. The grates are set in open bearings so it is easy to put in or take out bars. The distance between the grate bars is always uniform and the bars and hangers are in one piece, being constructed each with a separate link. A standard is screwed to the boiler front, and a fork lever works in it when shaking.

The peculiar shape of the pieces in the grate bars does the work of breaking the clinkers. One tooth is convex, the other concave; the concave tooth on one bar works on the convex tooth on the opposite bar. The clinkers fall between the bars, which, while shaking, break and drop them to the bottom of the ashpit.

THE EDDY AUTOMATIC SMOKE RECORDER

The Hamler-Eddy Smoke Recorder Co., Chicago, Ill.

More attention is continually being paid to maintaining the cleanliness of our cities. In the municipalities where bituminous coal is extensively used, improved coal burning apparatus has been installed which if properly manipulated will maintain a stack free from smoke, improperly operated, this elaborate equipment will deliver to the stack, smoke of the greatest density.

The owners of offending stacks frequently equip their plants with stokers or other smoke consuming devices of improved types, still upon the faithfulness of the fireman rests the success or failure of this equipment.

It is not uncommon to keep a man on the roof with a telephone handy to warn the fireman when smoke appears. In other cases a camera has been employed and various efforts have been made to record the time and density of the smoke.

The Eddy automatic smoke recorder illustrated herewith is a device which is an accurate telltale on the time, duration and density of shade or color of the smoke at the top of the stack. The instrument has been reduced to a fine point of simplicity and requires practically no attention aside from the changing of charts. It can be located as far as 100 ft. from the stack, in the engine room or other convenient place. Samples of flue gases are drawn by the instrument through a ⅛ in. pipe and impigned against a revolving chart operated by clock-work. The chart is cross-ruled for hours and minutes.

The mechanism is mounted on a 10 by 22 in. base and consists of a ½-hp. motor, that through a speed-reducing transmission, drives the pump; this in turn actuates the necessary flow of gas. The gas is first drawn through a condenser and then forced over the surface of sulphuric acid on its way to the chart, a typical section of which is shown in Fig. 2.

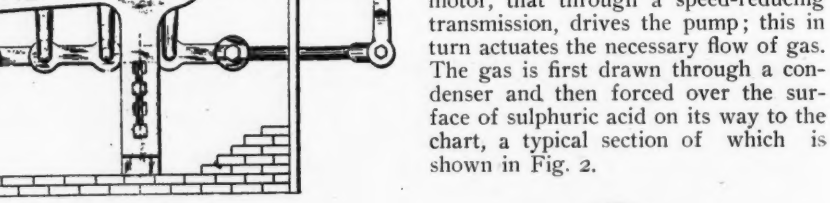


FIG. 1.—EDDY AUTOMATIC SMOKE RECORDER

W. H. Salisbury & Co., 166 Wabash Ave., Chicago, has taken the agency for Northern Illinois and Northern

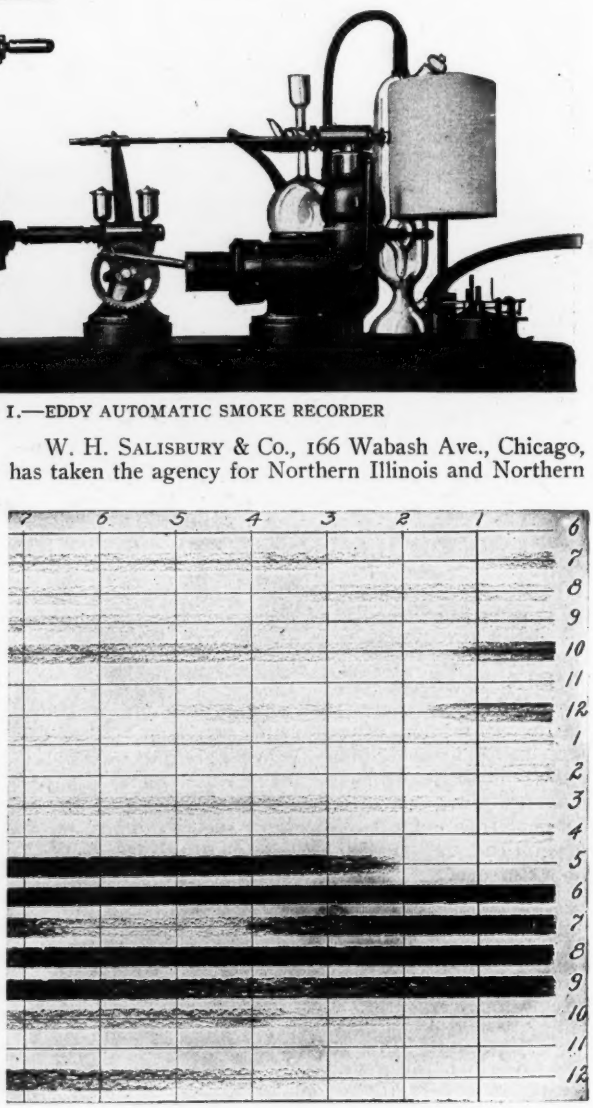


FIG. 2.—RECORD FROM SMOKE RECORDER

Indiana for Vanda Packing and will carry a full supply in the Chicago store.

NEWS NOTES

DIRECTORS OF THE ALASKA-YUKON Exposition have recently notified the Goulds Manufacturing Co. that the highest awards were given to that company for its exhibit of triplex pumps.

THE MISSOURI, INLAND & SOUTHERN R'Y CO. is now ready to correspond with contractors relative to grading about 50 miles of road-bed. It wishes also to hear from parties in regard to rails, equipment and everything necessary in the construction of a steam railway.

THE COLLISION BETWEEN A PENNSYLVANIA eastbound passenger train and an empty engine just outside Jersey City on the morning of Nov. 8 resulted in comparatively few injuries to the passengers, due to the fact that the strong frames of the passenger cars resisted crushing. The damage to engines and cars, however, was considerable. One of the steel passenger coaches jumped the track and turned over on its side, denting in the steel plates about 18 in.

In the lighting equipment of this car were 9 General Electric Tungsten lamps. It is interesting to note that, after the wreck, when all the lamps were taken out and tested, the Tungstens were found to be in perfect condition—a further proof of the rather remarkable strength and durability of the Tungsten filament when specially adapted for train lighting service.

THE LUNKENHEIMER COMPANY, of Cincinnati, Ohio, manufacturers of high grade engineering specialties, tendered their employes and families a Thanksgiving dance in one of their new factory buildings, on Wednesday evening, Nov. 24. About 3000 people attended. An elaborate luncheon was served and all present thoroughly enjoyed themselves and voted the dance a great success.

TO ASSIST IN THE PROBLEM of lessening the danger of mining and the frequency of mine explosions and caveins, the United States Geological Survey is issuing a Primer on Explosives which will show the coal miner how to be careful in the handling of these materials.

PAUL M. CHAMBERLAIN wishes to inform his friends that he has opened an Engineering Office, and is prepared to furnish plans, estimates, and superintendence for new plants, and the improvement of old ones. He will give especial attention to power plant and factory equipment, fuel economy and smoke abatement. His previous connections as engineer with Frick Company of Waynesboro, Pa., Hercules Iron Works of Aurora, Ill., McGan Mechanical Works of Los Angeles, Cal., and The Underfeed Stoker Co. of America, together with consulting work while professor of mechanical engineering at Lewis Institute, Chicago, prepares him to serve clients to their best advantage.

FOUR ASSOCIATIONS OF THE NATIONAL Association of Stationary Engineers in Philadelphia combined for the purpose of giving a grand concert, supper and dance at Lulu Temple, Friday evening, Dec. 3. This affair was an unqualified success from every point of view, attended by nearly 1000 engineers and their ladies.

Among those present were: National President William Reynolds, Hoboken, N. J.; National Treasurer Samuel B. Forse, of Pittsburg; Fred Markoe, the supreme chief engineer of the American Order of Steam Engineers; Joseph F. Carney, past national president of New York; James D. Lynch, past national president; L. L. Rice, manager of the National Engineer of Chicago.

The concert was opened by an organ voluntary on the grand organ, followed by a concert by the New York Supply Men's bunch. An elaborate menu was served, after which a dance until the wee small hours of the morning.

The committee in charge of this affair was: L. K. Covington, of National State Association No. 1, chairman; Enoch Carless, of Tacony Association No. 9, treasurer; E. Caldwell, American Association No. 12, secretary; G. F. Duemler, Northeast Association No. 20, corresponding secretary.

NEW CATALOGS

FROM THE B. F. STURTEVANT CO. comes a convenient catalog entitled "What We Make," which will be found of the greatest convenience in every engineer's reference library. It gives a resume of the Sturtevant products in blowers, exhaust fans, blast gates, forges, pneumatic systems, for conveying light material, propeller and disk fans, exhaust heads, mechanical draft systems, heating and ventilating systems, drying kilns, steam turbines, steam engines, and electric dynamos, and motors. It is one of those books which serves as a ready reference to tell us exactly where to go for complete information on any one of these lines, and is so written and illustrated as to give a clear idea in brief form of what each line of apparatus is intended to accomplish. It can be had by writing to the company at Hyde Park.

"DIVIDENDS AND DRIVES" is the title of an attractive little booklet issued by the Dodge Manufacturing Co., Mishawaka, Ind., and shows how the rope drive system can be applied to almost any sort of transmission work.

CATALOG C OF THE ALBERGER PUMP CO., of New York, describes in detail the Alberger centrifugal pumps, showing by numerous illustrations the different types and styles, and by geographical diagrams the capacity and efficiency which may be secured with varying speed. The efficiency curves in particular are notable and show a 10 in. single stage turbine pump running to as high as 72 per cent and for a 5 in. three stage pump as high as 63 per cent. A novelty in the way of cuts is the sectional views showing the running parts in solid black with the castings and guide vanes sectioned so as to be easily distinguishable. The application of Alberger Centrifugal Pumps and Condenser Practice is also interestingly shown.

MECHANICAL CONTROL OF AIR AND COAL is the title of a booklet recently issued by the American Ship Windlass Co., Providence, R. I., in the form of a description of the Taylor system of combustion. It is shown that this system has been perfected by the use of a furnace suited to the coal used, and by mechanically controlling the supply of air and coal. The Taylor gravity under-feed stoker provides the proper furnace conditions and supplies the coal; a mechanical draft fan furnishes the air.

THE WATSON STILLMAN CO., of New York City sends out a novelty in the line of a return postal card and folder describing the Watson Stillman Twin Volute turbine pump, for tank service and drainage, and it describes also an automatic method of switch control for regulating motor driven pumps of this type.

THE L. S. STARRETT CO., of Athol, Mass., issues a supplement to Catalog No. 18, showing a new line of tools, including a bevel protractor, a combination square, a planer and shaper gage, taper and thickness gages, draftsman's protractor, some new styles of calipers, and dividers, automatic adjustable stroke center punches, level side attachments, special steel rules, etc.

TRADE NOTES

IN OUR ISSUE FOR DECEMBER we made the statement that the Lunkenheimer Co. had on hand folding steel rules for distribution. This was made with a misunderstanding, as these rules were given out at the Columbus convention but no surplus supply is on hand and the company is unable to furnish rules to those who desire them. It is only fair to the Lunkenheimer Co. to state that the item as published in the December issue was not submitted to them and that they are not responsible for the statement made in it. The company states, however, that it will be glad to furnish a copy of its catalog to all interested in lubricating specialties for power plants. Our readers will appreciate that the item was published in agreement with our usual practice of wishing to bring to the attention of all subscribers the interesting news and good things of the power plant field and that it was purely in their interests that the statement was made. We regret the mistake and would offer our apologies both to the Lunkenheimer Co. and to readers for any inconvenience caused.

"STEEL MIXTURE" FIRE BRICK is a good representative in its qualities of the name given it by the manufacturers, McLeod & Henry Company of Troy, N. Y. This company, which was founded in 1825, is issuing a new and attractive as well as instructive catalog, showing the different methods of using "steel mixture" brick in installing boiler settings. It is used for boiler door arches, fire box sides and bridge work of furnaces, for back arches, for combustion arches, for Dutch ovens and in fact anywhere that fire brick may be used. The catalog is worth owning.

THE SOUVENIR SPRING PAPER CLIP and weight sent out by the Sight Feed Oil Pump Co. of Milwaukee, Wis., to visitors at the Columbus Convention, is one which will make glad the recipients and will bring frequently to their minds the courtesy of the company. Like the Richardson pumps, which the company makes, it is a substantial, durable article.

PRACTICAL ENGINEER CLASSIFIED ADVERTISEMENTS

Advertisements in this section are inserted under regular headings at the rate of 40 cents per line. About nine words make a line. No display type is allowed, but the first three words may be set in capital letters. Minimum space sold, two lines.

Under classification, "Positions Wanted," advertisements not exceeding four lines will be inserted for subscribers once free of charge.

To insure proper classification, copy must reach this office on or before the 15th of month preceding publication.

Positions Wanted

CHIEF ENGINEER wants position as master mechanic or chief engineer in large establishment; high-speed Corliss engines, ice machines and dynamos; thoroughly competent. Address Box 123, Practical Engineer. 1-2

AS ENGINEER—By experienced steam-electric engineer holding Montana first-class license. Experienced with high speed and Corliss engines, and boilers of all types; 10 years' experience. Address Box 120, Practical Engineer. 12-2

POSITION WANTED—By engineer, strictly sober, 12 years' practical experience with boilers, chain grate stokers, slide valve and Corliss engines, D. C. dynamo, pumps. Own indicator outfit, and am proficient in its use. State salary. Box 124, Practical Engineer. 1-2

ENGINEER AND ELECTRICIAN to take charge of your power plant. Experienced in rope and electrical transmission of power. Well up in modern appliances for economical power production. How is your plant, Mr. Owner—bad? Want better results? Let me hear from you. Want to change to western town. Address Box 21, Practical Engineer. 12-2

POSITION WANTED—As assistant engineer. Seven years' experience, also nearly completed course in I. C. S. Can furnish good references. Address F. F. Ninman, Belle Plaine, Wis. 12-2

Wanted

WANTED—One copy of February, 1909 issue of Practical Engineer. Will pay you 50 cents for it. Address C. Bestenheider, 106 Hull St., Brooklyn, N. Y. 1-1

Help Wanted

NICE SIDE LINE for steam specialty salesmen. Reiter Boiler Cleaner Co., Elgin, Ill. 9-tf

AGENTS WANTED to sell Burgmann celebrated engine packings in territories not yet covered. See our advertisement on page 15 of this issue. 9-tf

WANTED—An experienced turbine engineer to take charge of a new turbine electric power station now being erected. Give experience and reference; also state salary desired. Address Box 122, Practical Engineer. 12-2

WANTED—Salesmen calling on power plant trade to handle small line of steam specialties for everyday use, by established manufacturing concern with reputation for high-grade material. Liberal commissions to energetic, reliable men. Address W. T. Jameson, 100 Surrey Rd., Mansfield, O. 1-1

ENGINEERS AND MECHANICS—To make big money selling Incomparable "TIZ" Hand Soap. A 10-cent can will instantly remove more dirt and stains from the hands than four cakes of any soap made, and it will not injure the most delicate skin. Small sample free. Byram Mfg. Co., Box 3133, Boston, Mass. 4-tf

For Sale

FOR SALE—60 steel storage tanks, 6,000 gallons' capacity. Good as new. Double riveted, extra well built. Suitable for storage of oils, waters or liquids of any kind. 100 steam pumps. Get our prices on engines, boilers and electrical machinery. All sizes and kinds. Chicago House Wrecking Co., 35th and Iron Sts., Chicago.

Machinery For Sale.

FOR SALE—8- H. P. traction gasoline engine, feed cutter and wood saw. Geo. C. Schemmel, Wapakoneta, O. 1-1

FOR SALE—ENGINES AND BOILERS—Corliss—Heavy Duty, 18 x 36 Ohio, 24 x 30 Clark, 22 x 48 Allis. Girder Frame, 14 x 30 Bass, 18 x 42 Allis, 22 x 42 Hamilton, 28 x 54 Hamilton. Automatic—All sizes, 30 to 400 hp. Send for list. Throttling engines from 10 to 100 hp. Woodworking machinery of all kinds. Cleveland Belting & Machinery Co., 1922 Scranton road, Cleveland, Ohio. 9-tf

Patents and Patent Attorneys

PATENTS—Watson E. Coleman, Patent Attorney, Washington, D. C. Advice and books free. Highest references. Best services. 4-tf

PATENTS—For a Canadian or foreign patent send sketch for free report. Patentability certificate given. Canadian patents taken up for sale if desired. Send ten cents for booklet and inventors' monthly magazine. Ben. B. Pannett, Ottawa, Ontario, near Patent Office. 9-tf

HAVE YOU AN IDEA? If so write for our books: "Why Patents Pay," "What to Invent," "100 Mechanical Movements" and a Treatise on Perpetual Motion—50 illustrations. All mailed free. F. Dietrich & Co., Patent Lawyers and Experts, Oray Block, Washington, D. C. 1tf

PATENTS—C. L. Parker, late Examiner, U. S. Patent Office, Attorney-at-Law and Solicitor of Patents. Patents secured promptly and with special regard to the legal protection of the invention. Handbook for inventors sent upon request. 186 McGill Building, Washington, D. C. 4-tf

Miscellaneous

ENGINEERS—Pack your Corliss valve rods with Ideal Metallic Packing. Three years' guarantee. Price per inch diameter of rod $1.00. Ideal Metallic Packing Co., South Stillwater, Minn. 8-tf

FREE, ANY FIRM owning a steam plant, or any engineer in charge of steam plant, that is troubled with scale and has to use boiler compound can get the best indicator and reducing wheel made, free. Address Great Lakes Chemical Co., Manitowoc, Wis. 10-tf